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Art. XXXIX.—*The Biela Meteors of November 27th*, 1885; by H. A. Newton.

Numerous notices of the brilliant meteor display of Nov. 27th (see p. 78) are given to us in the *Astr. Nachrichten*, the *Monthly Notices R. A. S.*, the *Observatory*, *Nature*, the *Comptes Rendus*, etc., by observers in various places over the Eastern hemisphere. The display in Western Europe occurred in the early evening hours, and it was reasonable to suppose that the shower would be visible over the Eastern Continent wherever the skies were clear. This seems to have been actually the case, though naturally the most valuable observations were made in Western Europe. There had been preparation for the shower by reason of anticipatory notices, especially one in a Dun Echt circular. Unfortunately in England, and at a few places on the continent, clouds seriously interfered with observing, though through breaks in the clouds much was seen notwithstanding.

Time of maximum.—The shower was in full activity in Europe at the close of twilight, and for a while increased in intensity. The time of the maximum was estimated.

At Pulkowa at	8h	15m	P. m. t.,	that is,	6h	14	Gr. m. t.
" Upsala	7	29·8	U. m. t.,	"	6	19	"
" Bonn (cloudy)	6	42	B. m. t.,				
" "	6	37	"	"	6	11	"
" "	6	40	"				

At Moncalieri the numbers given by P. Denza are:

6^h	0^m	to	6^h	15^m	Rome m. t.	2800	meteors	by	2	obs.
6	15	"	6	30	"	3100	"		2	"
6	30	"	6	45	"	3400	"		$2\frac{1}{3}$	"
6	45	"	7	0	"	4500	"		3	"
7	0	"	7	15	"	6200	"		4	"

The count was continued but clouds interfered. By a table quoted below we have for the ratio of the numbers of meteors visible to 2, 3 and 4 observers, 633 : 836 : 1000. P. Denza's observations reduced by these ratios show that the display increased in brilliancy until $7^h\ 15^m$ when the sky became partly overcast. The maximum indicated by them was then later than 7^h Roman, that is, $6^h\ 10^m$ Greenwich time. Professor Zona places the maximum earlier. Professor Cacciatori at Palermo gives $7^h\ 45^m$ (that is, $6^h\ 52^m$) as the time of maximum. But clouds are reported during the preceding half hour. Many other observers give times of the maximum display which are more or less indefinite. We shall assume $6^h\ 15^m$ Gr. m. t. as representing very well the mean of all the observations.

Duration.—From the time of maximum the intensity quite steadily diminished. The numbers counted at Upsala show the course of the shower. The weather was fine and twelve observers under the direction of Messrs. Hildebrand-Hildebrandson and Charlier, looking toward different quarters of the sky kept count by quarter hours through five hours, with the following result (Greenwich time).

5^h to $5\frac{1}{4}^h$, 2545	$6\frac{3}{4}^h$ to 7^h, 3383	$8\frac{1}{2}^h$ to $8\frac{3}{4}^h$, 799
$5\frac{1}{4}$ " $5\frac{1}{2}$, 2287	7 " $7\frac{1}{4}$, 2497	$8\frac{3}{4}$ " 9, 585
$5\frac{1}{2}$ " $5\frac{3}{4}$, 2906	$7\frac{1}{4}$ " $7\frac{1}{2}$, 2072	9 " $9\frac{1}{4}$, 502
$5\frac{3}{4}$ " 6, 3382	$7\frac{1}{2}$ " $7\frac{3}{4}$, 2295	$9\frac{1}{4}$ " $9\frac{1}{2}$, 375
6 " $6\frac{1}{4}$, 4213	$7\frac{3}{4}$ " 8, 1999	$9\frac{1}{2}$ " $9\frac{3}{4}$, 307
$6\frac{1}{4}$ " $6\frac{1}{2}$, 4422	8 " $8\frac{1}{4}$, 1336	$9\frac{3}{4}$ " 10, 268
$6\frac{1}{2}$ " $6\frac{3}{4}$, 3330	$8\frac{1}{4}$ " $8\frac{1}{2}$, 1341	

The numbers diminished so that at the end of three hours from the time of the maximum there were only one-tenth of the maximum numbers of meteors. The end of the shower was not a definite epoch. Assuming that there was an increase during the sunlight and the twilight corresponding to the later decrease we may say in general terms that the shower lasted as an extraordinary display through six hours. Some of the reports from observers in Asia give reason to believe that the increase was less rapid than the decrease. A few Andromeda meteors were seen in different places on the night of the 26th, 28th and 29th, but the number of them on each night was not large.

Hourly number of meteors at the time of maximum.—As has been noticed in other showers the meteors were not evenly distributed in time but came somewhat fitfully. There is moreover great discrepancy in the numbers counted by different observers. The numbers of persons counting, the precautions to prevent duplication, the relative directions in which they looked, and the state of the sky are in many cases not given, and this renders the comparison of numbers reported from different places difficult.

An experiment made in 1865 by the writer gave the following ratios (y) for the numbers of shooting stars seen by from one to twelve observers (x). The group of observers is presumed in each case to have the points toward which they are looking symmetrically distributed over the heavens.*

x	y	x	y	x	y
1	325	5	1106	9	1399
2	633	6	1200	10	1451
3	836	7	1282	11	1509
4	1000	8	1348	12	1560

These values of y should increase toward a limit when x increases indefinitely. The limit is evidently more than 2000, and as the differences near the end of the table decrease very slowly, I do not regard 2400 an extravagant estimate. I shall therefore use that factor in some subsequent computations.

Of the shower of Nov. 27th no published set of observations show more completely the course and intensity of the shower than those above cited made at Upsala. They imply at the maximum an hourly number of $4\times4422\times2400\div1560$ (that is about 27000) for the total number visible at Upsala. They also give for the quarter-hour number for one observer at their maximum $4422\times325\div1560$ (that is, about 60 per minute.)

At Marseilles three observers (Stephan, Borrelly and Coggia) in several trials counted over 600 per minute, which represents 233 per minute, for one observer and a *total* hourly number of over 100,000. At moonrise ($10\frac{1}{2}^h$) there were 50 to 60 a minute counted.

At Palermo the maximum number per minute reported was 214 for two observers from $7^h\ 43^m$ to $7^h\ 48^m$.

At Geneva 55 to 60 a minute were reported. The sky was partly clouded.

* Dr. Kleiber (*Astr. Nachr.*, No. 2621) has given a similar table from some observations made by him in 1884 at St. Petersburg. As he has in his discussion, however, taken every possible combination of his eight observers instead of considering such combinations as contain observers looking to different parts of the heavens, Dr. Kleiber's numbers and mine represent different quantities, and are not properly comparable. His method of reduction seems to me faulty, and to have vitiated his results for practical use.

At Glasgow one observer counted 74 in a minute at $6^h\ 10^m$, and another counted 100 in a minute at $6^h\ 24^m$.

At Greenwich there were 30 to 40 a minute for one observer between 6^h and 7^h.

From Beyrout, Professor Robert H. West of the Syrian Protestant College reports in *Nature* (vol. xxxiii, p. 152): "The maximum appears to have been between 8 and 9 o'clock. At $6^h\ 3^m$ two observers watching opposite parts of the sky counted 850 meteors in five minutes. At $7^h\ 50^m$ ($5^h\ 30^m$ Greenwich mean time) seven observers divided the heavens among them and together counted 525 in one minute. We all agreed that we had not been able to count all that we saw, so that this number is probably too small. At any rate I do not think the number of meteors visible between 7 and 9 P. M. was at any time less than 500 per minute. At 10^h I alone counted 210 in two minutes, facing the north, which was then partially clouded."

The number 525 for seven observers corresponds to $525\times 325\div 1282=133$ per minute for one observer, and to a total hourly number (computed as before) of 59,000. The count of 850 in 5^m for two observers represents 87 per minute for one observer.

At Moncalieri the 6200 for 4 observers in a quarter hour in like manner represents about 60,000 per hour for the total number visible.

In many other places larger or smaller numbers were reported. Over 100 in individual minutes were counted by a single observer in several places. It can hardly be doubted that there was a purer sky and so a larger number of meteors visible at Beyrout, Moncalieri and Marseilles than at Upsala and Greenwich.* In computing the hourly number of meteors visible we should choose the clearer rather than the hazy skies. Probably it will not be considered unreasonable to assume from these observations, that the density of the meteor stream in its central and densest portions may be fairly expressed by 75,000 meteors per hour visible at one place in a very pure clear sky by a very great number of observers.

By an extended examination of meteor paths it was shown in 1864 (this Journal, II, xxxix, p. 196) that *about one in fifty* (one in 50·35) of *all shooting stars visible at a place should have the middle points of their apparent paths within* 10° *of the zenith.* The hourly number of meteors within 10° of the zenith at the time of the maximum, Nov. 27th, was then 75,000/50, or 1500.

*It is not reasonable to suppose that the product of the number of meteoroids that entered the air near the several places multiplied by the cosine of the zenith distant of the radiant greatly differed. Can a different constitution of the upper strata of the atmosphere, by reason of which paths become more brilliant in one place than in another be admitted as possible?

Following a similar process of reasoning to that of the article referred to, we may compare the number N of meteor tracks which are visible during a given time at one place whose middle points are within 10° of the zenith, with the number N′ of tracks visible during the same time (not necessarily visible all at one place) whose middle points are in a right cylinder of circular base whose radius is r, and whose axis proceeds from the observer in the direction of the radiant. The following proportion is readily formed:

$$N:N'::\int_a^b \pi\rho x^2 \tan^2 10^\circ\, dx:\int_a^b \pi\rho r^2 \sec z\, dx::\tan^2 10^\circ \int_a^b \rho x^2\, dx:$$
$$r^2 \sec z \int_a^b \rho\, dx,$$

in which x expresses the height from the ground of middle points of meteor tracks, a and b the limiting values of x, z the zenith distance of the radiant, and ρ a factor proportional to the mean density of the meteor tracks at different altitudes, which is assumed to be a function of x only.

If we further assume that the values of ρ in the present shower are equal to those used in the memoir cited, and which were obtained from all the measured altitudes of shooting stars then available, we shall have for ρ at elevations of 45, 75, 105, 135 and 165 kilometers the several values 114, 243, 277, 106 and 57.

Using finite summation for integration we have,

$$\Sigma\rho\,\Delta x = 797\,\Delta x, \text{ and } \tan^2 10^\circ\,\Sigma x^2\rho\,\Delta x = 252930\,\Delta x;$$

hence the above proportion gives $N' = \cdot00315\, N r^2 \sec z$ where r is to be expressed in kilometers.

The radiant at the time of the maximum of the shower was vertical over the Caucasus, and the value of sec z for the several stations varied from 1·02 to 1·15. I shall use the value 1·08 for sec z, and 1500 for N for an hour. This gives $N' = 5{\cdot}1r^2$ for one hour, in other words, at the maximum of the shower there were 5·1 meteors per hour, the middle points of whose visible paths were in a fixed right cylinder whose axis was parallel to the relative motion of the meteoroids, and whose radius was one kilometer. But such a cylinder evidently received all the meteoroids of a cylinder of nearly equal radius located in the meteoroid group, and whose length was the hourly motion of the meteoroids relative to the earth before the earth began sensibly to attract them.

The velocity of the Biela meteoroids relative to the earth (using the orbit of 1852), is found by Weiss to be ·53484. (Beiträge zur Kenntniss der Sternschnuppen I, p. 11.) The earth's velocity being 29·8 kilometers per second, we get

57,300 k. for the meteoroid's relative velocity per hour. *The space in the meteoroid group corresponding to each single visible meteor was therefore, in the densest portion of the group, a cube whose edge in kilometers is the cube root of* $57{,}300\pi/5{\cdot}1$, *that is*, 32·8 *kilometers*, or 20·4 miles.

Thickness of the stream of meteors.—As the earth has a velocity of 18·5 miles a second and its orbit has an inclination to the stream of 12° 33′, the earth's motion perpendicularly to the stream is 14,500 miles per hour, or 87,000 miles in six hours. The really dense portion of the stream was then less than 100,000 in breadth and nearly all of it was included in a belt 200,000 miles in thickness. One hundred thousand miles subtends at the sun an angle of 3′·7.

Radiant of the meteors.—Nearly every observer paid special attention to the radiant, so that perhaps at no previous time has there been so generally an effort to determine its position accurately as in the present shower. The result is correspondingly instructive. I have collected in the following table a considerable number of places assigned for the radiant, applying in a few cases a correction for precession to reduce from the date of the chart to the equinox of 1885·0. With some of these there is given the hour of the evening to which the radiant belongs, but the larger part are without such an indication. Five of them reported by Mr. Denning, at Bristol, are for preceding and following evenings. About seven-eighths of these tabular places are represented in the accompanying figure, p. 417, the remaining places being beyond its limit. The Pulkowa observations are plotted with R. A. 25°·5.

Place.	Observer.	R. A.	Dec.
Agra,	Strahan,	26°·2	46°
Mauritius,		near	γ Andr.
Beyrout,	West,	25·5	43·5
Athens,	Lephay,	21	32
Pulkowa,	Romberg,	24–27	44
"	Backlund, etc.,	24–27	46
"	H. Struve,	24–27	48
"	O. Struve, etc.,	24–27	50
"	L. Struve, etc.,	22	53
"	"	24	44
Upsala,	Gyllenskiöld,	23·7	44·4
"	"	22·3	44·2
"	"	21·0	44·2
"	"	25·6	45·9
"	Fineman,	22·6	41·5
"	"	22·15	44·9
"	"	21·65	45·4
"	Charlier,	23·4	45·0
"	"	24·6	45·5

Place.	Observer.	R. A.	Dec.
Upsala,	Charlier,	23·9	47·3
"	Schultz—Steinheil,	25·2	42·5
"	Meyer,	22·05	46·4
Helsingfors,	Donner,	22·5	53
Vienna,	Weiss,	near	γ Andr.
Prague,	Weinek, etc.,	"	"
"	Safarik,	21·5	42
Breslau,	Galle,	27·1	43·9
"		27·7	43·5
Tuschkau,	Kaschka,	30·8	49·4
Königsberg,	Rahts,	23·1	43·8
"	Franz,	24·4	44·3
Berlin,	Förster,	25·7	43·2
"	v. Sichart,	25	45
Bremen,	Meinardus,	17	45
Leipzig,	Bruns,	22·6	48
Munich,	Oertel,	near	γ Andr.
Patenkirchen,	Ward,	"	χ "
Bonn,	Schönfeld,	24·7	44·2
"	Deichmüller,	16·4	44·9
Cologne,	Klein,	near	γ Andr.
Arnsberg,	Busch,	22	39
Essen,	v. Heyden,	30	50
Osterath,	Meller,	24	42
Malta,	Scoles,	21	46
"	v. Tucher,	27·7	42·5
Palermo,	Zona,	22·4	42·6
"	"	22·9	41·9
"	"	24·4	40·9
"	"	23·4	41·8
"	Ricco,	25·4	41·1
Milan,	Schiaparelli,	15	45
"	"	18·5	44
"	"	23	42
Moncalieri,	Denza,	22	44
"	"	26	43
"	"	28	42
Geneva,	Kammermann,	24	41
Deventer,	Sirks,	23	42
Sneek,	Nyland,	21	42
Enscheele,	v. Deinse,	22	43
Dongen,	v. Boxel,	25	39
Ougrée,	DeBall,	22	42
Nice,	Perrotin,	24·2	43·1
Marseilles,	Stephan, etc.,	22·5	49·2
Grignon,	Jehl,	23	42
Bordeaux,	Rayet,	28·5	46
Alton,	Howlett,	near	γ Andr.
Chepstow,	Lowe,	"	"
Bristol,	Denning (26)	26	44

Place.	Observer.	R. A.	Dec.
Bristol,	Denning (26)	27	43
"	" "	26	43·5
"	" (27)	24	43·5
"	" "	23	45
"	" (28)	22	43·5
"	" (30)	21	42·5
Harrow,	Tupman,	27	44
"	"	22·5	45·5
Greenwich,	Nash,	20	49
Stonyhurst,	Perry,	24	41
Oxford.	Stone,	22·5	42
"	Wickham,	10·3	52
"	Plummer,	21	45
"	Jenkins,	23	46
Dun Echt,	Copeland,	25·9	46·4
Dundee,	Smieton,	21	44
Glasgow,	Grant,	24	45·5
Cape Town,	Gill,	39	27
New Haven,	Newton,	near	γ Andr.
Cambridgeport,	Sawyer,	22·5	42·5
Princeton,	Young,	27·5	43·5

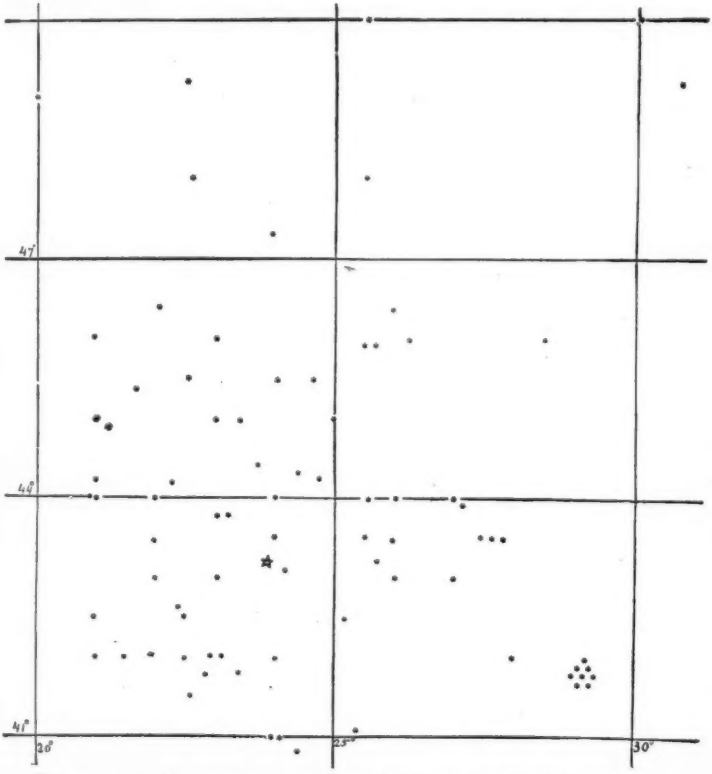
The object of forming this table is not to obtain the best possible observed place of the radiant. If this had been intended, there are many indications that some observations are entitled to considerable confidence and that some are not much to be relied on. The object is rather to bring out distinctly the fact that the radiant was not a mathematical point nor even a very small area. A considerable number of the observers distinctly stated that the tracks did not radiate from a point. Some thought there were two or more centers of dispersion. The same want of strict radiation from a center has been noticed in nearly every star-shower since 1833, the time when radiation was first noticed, and is shown equally when the tracks near the radiant are charted, and when the observer watches the stars near the radiant for the very purpose of deciding this question. Of course tracks beginning at a great distance from the radiant are of little use in determining the size and shape of the radiant area.

There are two corrections that should in strictness be applied to all these assigned positions, one for the zenithal attraction, and one for the observer's motion with the earth's rotation. The Biela meteors have a slow initial velocity relative to the earth, equal to 9·9 miles a second, and the same is increased before the earth's surface is reached to about 12 miles a second. Not a little deviation from the original direction is by reason of this slow velocity caused by the earth's attraction. The deviation is in the vertical plane, and is a function of the zenith distance very much like refraction.

The observed radiant is nearer the zenith than the original direction with which meteors approach the earth.

An approximate correction for this cause can be easily computed. For this we may disregard the height of the air, and assume that the meteors come to the ground. Also, the meteors may be regarded as coming in a hyperbolic orbit from an infinite distance instead of being only for a finite distance within the dominant influence of the earth's attraction.

Chart showing the places assigned to the radiant. The cluster is at γ Andromedæ. The large star is the place of the radiant corresponding to the Biela orbit of 1852.



Let us consider a single meteor that comes to the earth's surface, at the observer's place. The tangent to its path would then be directed to the observed radiant of a group that moved parallel to this single meteor. Let z be the angle which this path makes with the vertical line of the observer and x be the

quantity sought, namely, the angle through which the direction of path has been changed. The asymptote of the hyperbola makes then an angle $z+x$ with the vertical. Let the velocities at infinity, at the earth's surface, and what should be attained, at the perigee of the hyperbolic orbit, be respectively v, v_1 and v_0; let p, p_1 and p_0 be the perpendiculars upon the corresponding tangents; let g, a, b, and e, be the force of gravity, the semi-axes and the eccentricity of the hyperbola; let θ be the angle at the earth's center between the lines to the observer and to the center of the hyperbola, α the angle between the original direction of the meteor and the conjugate axis of the the hyperbola, and r the earth's radius.

Then we have,

by conservation of areas, $$vp=v_1p_1=v_0p_0; \quad (1)$$

by conservation of energy, $$v_1^2-v^2=2gr, \text{ and } p_0(v_0^2-v^2)=2gr^2; \quad (2)$$

by nature of the hyperbola, $$\begin{cases} a=b\tan\alpha,\ p=b,\ e=\operatorname{cosec}\alpha, \\ r(1+e\cos\theta)=a(e^2-1), \quad (3) \\ p=p_0(\tan\alpha+\sec\alpha), \quad (4) \end{cases}$$

Also $$p_1=r\sin z.$$

From (4) $$\frac{p}{p_0}-\frac{p_0}{p}=2\tan\alpha,$$

and from (1) and (2) $$\frac{p}{p_0}-\frac{p_0}{p}=\frac{2gr^2}{pv^2},$$

hence $$\frac{gr^2}{v^2}=p\tan\alpha=b\tan\alpha=a. \quad (5)$$

Again from (1) and (2) $$\frac{v_1}{v}=\left(1+\frac{2gr}{v^2}\right)^{\frac{1}{2}}=\frac{p}{p_1},$$

hence $$b=p=r\sin z\left(1+\frac{2gr}{v^2}\right)^{\frac{1}{2}}=\sin z(r^2+2ar)^{\frac{1}{2}} \quad (6)$$

and from (3) $$\cos\theta=\frac{a}{r}\frac{(e^2-1)}{e}-\frac{1}{e}=\frac{a}{r}\cos\alpha-\sin\alpha. \quad (7)$$

But evidently $$\theta+z+x=\frac{\pi}{2}+\alpha, \quad (8)$$

since each member is equal to the angle between the transverse axis of the hyperbola and the asymptote. The equations (5), (6), (7) and (8) enable us to compute a, b, α, θ, and x for given values of z. Taking $g=32{\cdot}12$ feet, $r=3956$ miles, $v=9{\cdot}9$ miles, we obtain this table of values of x with argument z.

z	x	z	x	z	x
10°	1° 0′	40°	4° 9′	70°	8° 0′
20	2 1	50	5 19	80	9 35
30	3 3	60	6 36	90	11 22

Hence we may say that *the earth's attraction changes the radiant of the Biela meteors toward the vertical of the observer,*

one-tenth of the observed zenith distance of the radiant. When the radiant is near the horizon the change is somewhat greater than one-tenth of the zenith distance.

The radiant was to the east of the greater number of observers until the shower had nearly ceased, and the correction would be generally under 2°, though in some cases exceeding that amount.

A second correction to the observed place of the radiant is required by reason of the motion of the observer due to the rotation of the earth on its axis. This correction must be applied before the observed places can be compared with each other, or with a radiant deduced from the orbit of a comet. For the Biela meteors this may be easily shown to be about 1°·0×sine of the arc from the east point of the heavens to the radiant and is to be applied to increase that arc. It is nearly constant for the European observations in the table.

These two corrections do not appear, however, to bring the scattered radiant positions any nearer together. We cannot, therefore, regard the earth's attraction and rotation as having much to do with their wide distribution over the constellation from which the meteors proceed.*

The luminous portions of meteor tracks are usually to the eye arcs of great circles. It is only in rare cases that the path appears curved. The luminous paths of the meteors were therefore straight lines, but were not parallel lines, for had they been parallel, the radiant should be a mere point, and not an area. How much they deviated from parallelism it is not easy to determine with exactness. That their directions differed from the average direction of the group by angles which for a considerable fraction of the whole number of meteors amounted to several degrees, seems a proper and necessary inference from the wide scattering of the radiant points as described by the observers and represented in the figure on page 417. Mr. Denning says (Mon. Not. R. A. S., xlvi, p. 69), "The area of radiation must have been fully 7° in diameter to accommodate the discordances in the flights. The center was at 24°, +44°, but I saw several very short paths from a point south of γ Andromedæ. I noted many of the meteors with the utmost care in order to assure myself of the diffuseness of radiation, and it was found impossible to get a sharply defined position.

* Since writing the above, Professor Fœrster's paper, in No. 2720 of the Astr. Nachr. containing a discussion of thirty-two assigned positions of the radiant in this shower has been received. He applied the above two corrections to the observed places, and gives the reduced R. A. and declination of each assigned radiant. If the means of the observed R. A.'s or declinations be taken, and their deviations from the observed added together (neglecting sign), the sum is 97°·7. But if the corresponding sum of differences be taken for his reduced places, the sum is 98°·8. In other words, the radiants are equally scattered before and after correction.

The contrary effect was indeed so obvious as to arrest the eye whenever simultaneous bursts of about six or seven meteors took place near the radiant. It was then seen that the collective flights were not symmetrical emanations from a central point. They rather appeared to be discharged in a loose, disjointed fashion from a comparatively large space on the N.W. region of γ Andromedæ, and just perhaps enveloping that star within its limits." Similar testimony is given by other observers.

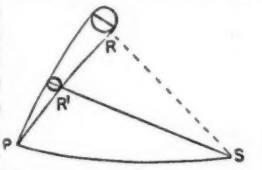
We must then accept one of two propositions: either the luminous paths are not true continuations, unchanged in direction, of the orbital paths of the meteoroids as they approach the earth; or else these orbital paths make angles of several degrees with their mean direction. The first alternative seems the more probable.

The meteoroid is probably a fragmentary body of irregular form. The meteorites which come to the ground are fragments, and nothing in their structure suggests a spherical or otherwise regular form upon entering the air. A small irregular body could not traverse with great velocity a fluid, even a fluid of extreme rarity, without there being developed such unsymmetrical resistance as would cause a curvature of path or glancing of the stone. This unsymmetrical resistance would continue so long as the stone retained its original irregularity. But in time the condensed air in front of the stone becomes hot enough to melt or burn off the stone. The thin angles in front must of course burn first. The melted matter being wiped off by the atmosphere, the anterior surface is rounded in such manner that the resistance of the air upon the stone becomes symmetrical. Thenceforth the path, now a luminous trail, is in general a right line. Curvature of path is an exceptional instead of an ordinary occurrence.

This rounding of one or more sides of the body is very clearly shown in many meteorites. Thus the Emmet Co. meteor broke into a very great number of large and small irregular fragments, and the small fragments retained enough velocity to burn after leaving the parent mass. Rounded surfaces evidently produced by the melting and wiping off of the material by the air are characteristic of these smaller pieces, several thousands of which have been collected.

The alternative proposition is that each luminous path is a portion continuous in direction, of the meteoroid's orbit about the sun and earth. Upon this hypothesis the orbits of different members of the group are not parallel, but the motions relative to the earth differ in direction by angles which amount in some cases to many degrees. The mean of the deviations from a common direction would be measured by degrees and not by minutes.

Suppose the directions of the luminous paths regarded as right lines to be first corrected for the earth's attraction and rotation as heretofore indicated, and the corrected lines to be produced indefinitely. They will intersect the celestial sphere in and near the constellation Andromeda. The most of the points will lie in an area comparable in size with the area dotted over by the assigned radiants, as shown in the figure on p. 417. Probably the points would be somewhat more widely distributed than the assigned radiants, since these latter are *centers* of radiation deduced each from many observed paths. Let an area R be taken on the celestial sphere that shall contain the principal part of the points so determined, an area that for convenience may be taken of an oval form. To this area R corresponds a second area R′, such that R′ bears the same relation to the motion of the meteoroids relative to the sun as R does to the undisturbed motions relative to the earth. The area R′ may be thus constructed. Let P be the point of the celestial sphere from which the earth is moving. To any point in R will correspond a point in R′ co-planar with P and conversely. Hence great circles from P touching R will be tangent to R′. If u be the earth's velocity, and v the meteoroids' velocity relative to the sun (which may be assumed to be the same for all the meteoroids), then by the law of composition of velocities, $v : u :: \sin PR : \sin RR'$. The dimensions of R′ for the Biela meteors will be easily found to be in one direction about $\frac{1}{3}$, and in the other about $\frac{2}{3}$ of the dimensions of R. Therefore for the shower of Nov. 27th, R′ is measured by degrees rather than minutes.



If the orbits of the Biela meteoroids were nearly (or quite) co-planar the area R′ would be a narrow oval (or a mere line). And if S be the earth's place as seen from the sun at the time of the shower the major axis of the oval (or the line) would be co-planar with S.

But to each point in R′ corresponds a point in R, and if R′ is a narrow oval (or line), R will also be a narrow oval (or line, which would be in fact, a portion of a sphero-conic). The lengths of lines in R will be to the lengths of corresponding lines in R′ in ratios not much greater than 9 : 4, nor much less than 3 : 2.

Now the thickness of the dense part of the stream subtends at the sun as was seen, an angle of about 3′·7. Therefore, either there is something like a nodal point of the meteoroid orbits near where the earth's orbit cuts them, or else the deviation of the planes of the orbits from their mean plane is generally not greater than one-half of 3′·7. Because a large group of orbits whose planes intersect the mean plane at angles

near 90° distant from where the shower happened would give a stream of meteors nearly equal in thickness to the radius of the earth's orbit into twice the limiting angle of the inclinations of the individual orbits to the mean orbit.

Unless therefore there is a nodal region for the several orbits near the ecliptic the area R′ must have a breadth not much greater than 3′·7, and consequently R a breadth not much greater than 6′ or 8′ in a northerly and southerly direction.

Again if the meteoroid orbits are nearly co-planar, and we compare two orbits corresponding to two points at the extremities of the narrow area R′, it is easily seen that the tangents to these two orbits make an angle with each other equal to the length of R′. Now if two equal elliptic orbits of great eccentricity and a common focus cut each other at a small angle near perihelion the lines of apsides of the two orbits make an angle with each other, nearly twice that made by the orbits themselves at their intersection. Hence the major axes of the two orbits corresponding to the two extremities of R′ make an angle with each other nearly double the length of R′, that is, nearly the length of R. That is, if R is several degrees long E. and W., the lines of apsides of the meteoroid orbits are distributed over several degrees. The group itself therefore must have enormous extent nearly in the mean plane, especially at aphelion. This would be true even if we suppose that the orbits have a nodal point at the place where they cut the ecliptic. Such scattering seems inconsistent with present compactness of the group, and a common history.

That there should be nodal points, either of inclination of planes or of intersection of orbits, where the earth cuts the meteoroid stream might be supposed possible if we had but one meteor-swarm to consider. But the same hypotheses must be for like reasons extended to the Leonids, and Lyraids, and perhaps to the Perseids. Unless the earth has been the controlling body in the history of all these swarms such hypotheses are violently improbable.

The more reasonable explanation therefore of the large area of radiation of the meteors of the Biela and other star-showers is the glancing of meteors on entering the air. The burning off of the angles of the solid fragments as soon as burning begins makes them move in straight lines thereafter. The curvature of path otherwise should continue through the whole length of the luminous tracks.

This glancing is not confined to the Biela meteors. It was true of the Leonids and still more of the Perseids. It is reasonable to assume that it is true of all shooting stars. It is not therefore as simple a matter as some have supposed to separate meteors into groups, alloting them to different radiant points, or to establish the persistency or change of such points.

To the uncertainty of the observation of a path, which with the very best observers amounts to two or three degrees, is to be combined this uncertainty of the amount and direction of its early glancing, which amounts also to several degrees. Besides all this there is the uncertainty due to the fact that any point above the horizon in a meteor path produced backward may have been its radiant. Any radiant that has been determined from a small number of paths must be very unreliable, and if the observations of the paths themselves have not been published the value of such determination as a contribution to astronomy is still farther diminished.

Movement of the nodes of the comet's orbit, and corresponding change of date of the shower.—The longitudes of the nodes of the orbit of the comet were greatly changed between its discovery in 1772 and its last appearance in 1852. The earth at first passed the node in the second week in December, but a change of ten or twelve days had brought it down to Nov. 27th before 1852.

The following table contains the longitudes of the nodes of the orbit reduced to the equinox of 1885·0, together with the inclination of the orbit to the ecliptic, for the successive appearances of the comet. The corresponding quantities for 1859 and 1866 are added from the orbits computed by Michez, the computation having taken account of the changes of these quantities in the interval from 1852. Since 1866 the perturbations of these quantities have been small, since Jupiter has not been at any time very near to the comet.

Longitudes of the nodes and inclinations of the orbit of Biela's comet at its successive appearances.

Year.	☊	*i*	Year.	☊	*i*	Year.	☊	*i*
	°	°		°	°		°	°
1772	258·7	17·1	1833	249·0	13·2	1859	246·1	12·4
1806	252·4	13·6	1846	246·5	12·6	1866	246·0	12·4
1826	251·2	13·6	1852	246·3	12·6			

With the progression of the node corresponds a progression of the star-shower, and with the change of inclination corresponds a change of radiant to the south. In 1798, on the evening of December 6th, Brandes counted for about four hours as many as 400 shooting stars. They diminished rapidly after 10 o'clock. In 1838 Mr. Herrick, on the evening of December 7th, with an assistant, counted 93 meteors in an hour radiating "from a spot not far from Cassiopeia; or perhaps, more nearly, from the vicinity of the cluster in the sword of Perseus. The radiant, however, could not well be fixed within three or four degrees." Observations at New Haven and elsewhere show that the maximum was on that evening. In 1847 Professor Heis at Aix la Chapelle observed on the evenings of December 8th

and 10th and recorded 226 meteors, a portion of which he has classified as radiating from R. A. 22°, Dec. +55°. If from the meteors recorded by him on those two nights we select all those whose paths produced backward would pass near Cassiopeia or Andromeda, and at the same time make a considerable angle with the meridian, we have about 27 which cross the 20° hour circle north of 50° declination, and 9 south of 50° declination. The large north declination of 55° assigned by Heis for the radiant is, therefore, required by the paths as recorded. There is no indication of the time of maximum. In 1867, Zezioli on the evening of November 30th, saw seven meteors, which Schiaparelli assigns to the radiant, R. A. 17°, Dec. +48.

The great shower of 1872 had its maximum at Nov. 27·34, Gr. m. t. The mean of 90 assigned radiants considered as single points was given by Professor A. S. Herschel as R. A. 24°·54 Dec. +44°·74 (Monthly Notices R. A. S., xxxiii, p. 504).

The longitude of the earth at the times of these several dates is given in the following table (equinox 1885·0):

Table of sun's longitudes at the dates of meteor displays.

Year.	Long.⊙	Year.	Long.⊙	Year.	Long.⊙
1798	256°·2	1847	257°·7	1872	246°·1
1838	256·1	1867	248·4	1885	245·8

Since the Biela meteoroids are encountered at the *descending* node of the comet's orbit, the longitude of the ascending node and the longitude of the sun are quantities to be compared. It will be seen at once that on the first three of the six dates, viz: 1798, 1838, and 1847, the sun's longitude was about that of the node of the comet's orbit in 1772, differing from it by an amount easily explained by the action of Jupiter at some distance. On the contrary, the few meteors seen by Zezioli and the two grand meteor showers of 1872 and 1885 are related to the orbit of the comet since its near approach to Jupiter in 1841–42.

The change of declination of the radiant shows the same fact. Professor Weiss gives the radiants for the Biela orbits as follows (eq. 1850) [Beitrage, etc., p. 15]:

Year 1772	R. A. 18°·7	Dec. +58°·1
" 1826	" 22·8	" +47·7
" 1852	" 23·4	" +43·0

The meteors of the years 1838 and 1847 have a radiant corresponding very well with that of the 1772 orbit, while the radiants of 1867, 1872 and 1885 are well represented by that belonging to the orbit of 1852.

The comet approached Jupiter and was greatly perturbed in 1794, 1831, and 1841–42. It is very difficult to conceive of

any way in which the meteors of 1872 and 1885 could be sent around in such a thin stream as we encountered, and one so near to the plane of the comet's orbit, unless they were a very compact group, and were also very near to the comet, as late as its near approach to Jupiter in 1841–42. If they left the comet before that time the effect of Jupiter would not be the same on the meteoroids as on the comet, and if they at that time formed an extended group, such disturbance as the comet suffered would have scattered the group, and we should have had a much less brilliant star-shower in 1872 and 1885.

Assuming, then, that the comet and the meteoroids were very near each other, if not united, at the date 1841·5 it seems possible to compute the disturbing forces and the resulting orbit along which some of these bodies traveled from that date until they met the earth in 1872, and also the orbit along which others traveled to meet the earth, Nov. 27, 1885. The observed orbits of the double comets in 1845–46 and in 1852 furnish the basis of such a computation. Possibly the result will give evidence for or against a resisting medium in the solar system.

We are moreover entitled to conclude that the process of disintegration of the comet is quite rapid. The non-appearance of the comet in recent years has like significance.

The following is a summary statement of conclusions:

1. The maximum of the shower was near $6^h\ 15^m$ Gr. m. t.

2. Three hours after the maximum the numbers of meteors had diminished to one-tenth the maximum number, and it is not unreasonable to assume six hours as containing the principal part of the shower.

3. The total hourly number of meteors visible at one place in a very clear sky, to some one or other of a very large group of observers may at maximum be regarded as 75,000.

4. In the densest part of the meteor stream where and when the earth encountered it, the space that corresponded to each meteoroid was equal to a cube whose edge was about 20 English miles.

5. The dense part of the stream was not over 100,000 miles in thickness.

6. The *zenithal attraction* of the Biela meteors was about one-tenth of the observed zenith distance of the radiant.

7. The radiant was an area several degrees across.

8. It is reasonable to suppose that the meteoroids while in the upper part of the atmosphere, before the paths become luminous, changed direction by a glancing, due to irregularity of form. After the resistance has developed heat enough to melt or burn off projecting angles of the stones, and the tracks

become luminous, the forms of the bodies become rounded in front, and the paths described are straight lines.

9. The meteoroids encountered by the earth on the 27th of November, in 1872, and in 1885, did not leave the immediate neighborhood of the Biela comet earlier than 1841·5, and may be treated as having at that time orbits osculating that of the comet. The determination of the paths of these meteoroids through their five and seven last revolutions about the sun seems to be a problem capable of complete solution.

ART. XL.—*The Ultra-violet Spectrum of Cadmium;* by LOUIS BELL, Fellow in Physics of the Johns Hopkins University.

As the ultra-violet spectrum of cadmium has long served as a standard of reference in the measuring of other spectra it has seemed desirable to determine its principal wave-lengths with an accuracy greater than has been heretofore reached. Thus far all determinations of ultra-violet wave-lengths have depended, in general, upon the method devised by Cornu, that of photographing upon the same plate the lines in question and a series of direct reflections of the slit corresponding to known angles of deviation.

While this process is an ingenious one and has done good service in preliminary work, it is clear that the accuracy of which it is susceptible is decidedly limited. For in the first place it is liable to the errors that always attend the determination of an angle by a small number of measurements and in addition to the numberless minor difficulties that must attend the taking and measuring of small photographs when the dispersion used is not large and the focussing is mainly a matter of experiment. A casual examination of the wave-lengths given for the same lines by various experimenters will give a clear idea of the difficulties and faults of the method. Even the numbers given by such careful workers as Cornu and Hartley not infrequently differ by as much as one part in five thousand.

A radically different method has been used in making the determinations reported in the present paper. The apparatus used has been the great spectrometer in the physical laboratory of this university, armed with a concave grating of twenty-one feet focal length and containing, in the space of six inches, nearly 80,000 lines. An idea of the dispersion produced by this instrument may be formed from the fact that photographs taken directly in the focus of the third order are on a scale somewhat larger than that of Ångström's map. An eyepiece micrometer with a very accurate screw two decimeters in length answers for the exactness of all measurements made in the vis-

ible spectrum. As the overlapping spectra of different orders are focussed in precisely the same plane, and the great focal length of the grating ensures a perfect focus in photographs over a foot in length, the method of coincidences can be used with the greatest exactness throughout the ultra-violet.

In using this apparatus the method employed was in detail as follows:

The first step was to determine with the greatest possible accuracy, the wave-lengths of the principal visible lines in the spectrum of cadmium. As the source of light, poles were made from cadmium which had been subjected to fractional distillation in vacuo, and the spark taken between them from a good sized induction coil furnished with a quart Leyden jar and worked by twelve Bunsen cells. The poles were separated somewhat over a millimeter and placed as close as possible to the slit. The slit also received the image of the sun from a heliostat and quartz lens and was closed until either the solar or the cadmium spectrum could be seen with equal sharpness of definition. Then the cadmium line to be measured was put near the center of field of the eyepiece micrometer and micrometer readings were taken on solar lines of which the wave-lengths were very accurately determined. When the place of the cadmium line was reached the sunlight was cut off for a moment and a reading was taken on the cadmium. Then the light was readmitted and the measurements on the solar lines continued.

This process was repeated several times and since the utmost care was taken that the light from the poles and from the sun should fall upon the grating in exactly the same manner, the micrometer readings gave the wave-length of the cadmium line with a very high degree of accuracy. The error of a wave-length thus determined can in no case be as great as one part in a hundred thousand, and usually it is much less. Independent measurements made on different days do not differ by more than this amount.

The solar lines on which the exactness of the work depends are determined to one part in half a million so far as relative wave-length is concerned. The cadmium lines thus measured were seven in number, and had wave-lengths, 6438·77, 5338·50, 5379·22, 5086·09, 4800·15, 4678·39, 4414·19, being Mascart's first seven lines.

Next in order came the determination of the extreme ultra-violet rays. Cadmium fortunately has a very prominent group of lines near wave-length 2300. Therefore a photograph of the last three lines mentioned above, taken in the first order, would include this ultra-violet group in the second order. And since both orders were in focus together, the wave-lengths could be

very exactly determined by a simple linear measurement. Several photographs of this region were taken, and measured very carefully by means of a dividing engine provided with an accurate screw and reading microscope. To make sure of accuracy the slit was narrowed until only the strongest lines appeared, while the definition was exceedingly sharp. Five strong lines were thus measured, taking mean of measurements from four negatives, with the following resulting wave-lengths, 2321·14, 2312·83, 2288·01, 2264·88, 2264·42. It is highly improbable that these are in error by as much as one part in fifty thousand. The last two lines of this group form a sharp double which with the dispersion and resolving power usually employed appears as a single strong, broad line with a conspicuous nimbus, Mascart's twenty-fourth line.

Having thus determined both ends of the spectrum with a satisfactory degree of exactness, the next step was to connect them by a series of negatives overlapping each other considerably and sharp enough to yield accurate measurements for the positions of the principal lines. As the only object in view was the determination of a series of standard wave-lengths, no attempt was made to photograph the fainter lines, but the slit was narrowed to secure the best definition practicable.

The main difficulty to be met in photographing spark spectra with the concave grating is lack of light. In spite of the large size of the grating its great focal length reduces the light so much that with the spark apparatus available it was best to photograph mainly in the first spectrum, although several negatives were taken in the second as a check upon the work. A string of seven negatives was then taken, overlapping by a considerable amount, and covering in all a space of about 90^{cm}. Besides these, odd photographs were taken in both the first and second orders, to secure sufficient checks.

These photographs were then placed on the dividing engine previously mentioned and measured with the utmost care, each measurement being repeated several times independently. Various portions of the screw were used to eliminate errors, and the measurements were made as nearly as possible at the same temperature, so that errors due to expansion of the glass became practically inappreciable. The dispersion used was so great that one millimeter on the negative equalled 2·72 tenth-meters of wave-length, so that a small error in measuring could produce but a slight difference in the resulting wave-length. In fact, very good results could be obtained by simply measuring the photographs with an accurate scale, wave-lengths thus obtained agreeing to within one part in ten thousand. In case of each line measures were taken from both ends of the spectrum, and they agreed so closely that the probable error of the deter-

mination was in every case less than 0·1 tenth meter, and in many cases decidedly less.

The series of photographs contained about forty lines, of which some thirty were distinct enough to admit of accurate measurement. One or two of this number were somewhat troublesome on account of being quite nebulous, particularly one or two lines in the extreme ultra-violet. Some of the fainter lines were omitted and the total number of lines accurately determined in the entire spectrum was thirty, of which the wave-lengths are subjoined. The first column contains the values thus obtained, while the second and third respectively contain the values given by Hartley and by Cornu. The visible lines are included in the table.

Bell.	Hartley.	Cornu.
6438·77		
5379·22		
5338·50		
5086·09		
4800·15	4799·	
4678·39	4676·7	
4414·19	4414·5	
3611·75	3611·8	
3609·39	3609·6	3609·
3534·69	3535·0	
3466·70	3466·8	
3465·22	3465·4	3465·5
3402·68	3402·9	3401·5
3260·12	3260·2	
3251·77	3251·8	
3249·40	3249·5	3247·
3084·28	3084·3	
2979·87	2979·9	
2880·25	2880·1	
2836·45	2836·1	
2748·45	2747·7	2747·7
2572·95	2572·2	2572·3
2329·22	2329·5	
2321·14	2321·6	
2312·83	2313·6	2313·5
2288·01	2288·9	
2264·88		
2264·42	2265·9 (mean)	2265·5 (mean)
2193·98	2196·4	2194·5
2143·75	2146·8	2144·

In comparing these values it must be borne in mind that the determinations of absolute wave-length on which they are based are not the same, since the author's work is founded on the scale of Professor Rowland's photographed map. This is

based on a measure of absolute wave-length made by Mr. C. S. Pierce, which gives for D, 5896·22 against 5895·13 given by Ångström. Although the details of Pierce's work have never been published, it is without doubt far more accurate than Ångström's. Pierce's value, however, is somewhat too large.

If this difference of scale be taken into account the figures are brought into somewhat better accord, though there will still remain discrepancies. From the fact that these occur in parts of the spectrum where the author's measurements were direct and particularly free from sources of error, it seems probable that many of them may be due to the unavoidable errors in working with small apparatus by a method which several sources of uncertainty tend to vitiate.

Most of the wave-lengths determined in the present research are probably correct to within one fifty-thousandth part of their respective values, and probably in no case does the error reach 0·1 tenth meter. A greater degree of accuracy can be attained only by the use of a spark apparatus powerful enough to allow one to photograph freely in the higher orders.

The photographs were all taken on Stanley instantaneous dry plates, developed by the ordinary ferrous sulphate process. The average exposure was about thirty minutes. Thanks are due to Mr. C. T. Child for efficient aid in the photographic part of the experiments.

A number of interesting points were noted during the progress of the work. The relative intensities of the lines, while they agree upon all the negatives, often do not agree with Hartley's estimates. This is probably due to the individual peculiarities of the gratings, and shows how fallacious all such estimates are liable to be unless made on the same apparatus. It was curious to note how little the sensibility of the plates decreased, even in the extreme ultra-violet. The curves ordinarily given for the sensibility of silver salts apparently depend on sunlight, and hence really represent not so much the sensitiveness of the salts employed as the intensity of the solar spectrum after absorption by the earth's atmosphere. While in photographing the solar spectrum the time of exposure increases very rapidly in the ultra-violet portion, it must have been noticed by every one who has photographed metallic spectra that there is little trouble in reaching w. l. 2000. This fact is brought out with peculiar force in the author's negatives of the superimposed spectra of the first and second orders. Taking into account the fact that the first spectrum is somewhat the brighter there is really little difference in intensity between w. l. 4800 and w. l. 2200. The maximum intensity seems to be between w. l. 4000 and w. l. 3600 and at w. l. 2200 it appears to be about half the maximum. These are of

course only rough approximations, but they are sufficient to raise some rather interesting questions.

The great resolving power of the apparatus used in these experiments resulted in the discovery of several new double lines, notably the one at w. l. 2264, of which the components are quite sharp and of about equal intensity. A negative in the second spectrum showed lines w. l. 2979·8 and w. l. 2880·2 to be also doubles, each of them having a faint component on the side of greater wave-length. And this discovery brings out a rather striking analogy. The group having wave-lengths 2979, 2880 and 2836 and the prominent group of wave-lengths 3611, 3609, 3466, 3465 and 3402 are in relative distances, character and intensity, almost precisely alike. In each the first two lines are double and in each case the fainter component has the greater wave-length.

Now turn to the spectrum of zinc. The most prominent group in the ultra-violet is a triplet of wave-lengths, 3344, 3301, 3281. And further in the ultra-violet is another group, of wave lengths 2800, 2770, 2754, closely resembling the former in arrangement. If now these be compared with the cadmium groups before mentioned, the close analogy is at once apparent. Each zinc group has an analogue in the cadmium spectrum, somewhat expanded and of greater wave-length, but very similar in grouping and general character. A photograph of the former zinc group was taken in the second spectrum which disclosed the fact that, as in the corresponding cadmium group, the two first lines were double, each with a faint component on the side of greater wave-length. Ciamician has pointed out a similarity in the visible spectra, and as the spectra are more thoroughly examined the analogy becomes all the more striking. Plot to scale these zinc lines: 6360, 4924, 4911, 4809, 4722, 4679, 3344, 3301, 3281, 2800, 2770, 2754, 2557, 2501, and the following cadmium lines, 6438, 5338, 5379, 5086, 4800, 4678, 3609, 3465, 3402, 2979, 2880, 2836, 2748, 2572, and the extraordinary resemblance between the spectra is evident. So striking is it that it can hardly have escaped notice, but the discovery of the double zinc lines noted above so emphasizes it that it is worthy of more than passing attention. The resemblance extends not only to the grouping of the lines but to those individual peculiarities that every spectroscopist knows to be almost as characteristic of certain lines as their wave-lengths. In both spectra it is analogous lines that are longest in the spark, that are reversed in the sun, and that are most persistent in dilute solutions. Certain it is, that zinc and cadmium must have some great similarity in atomic structure, and the extent and meaning of this is a subject by no means unworthy of investigation.

ART. XLI.—*Communications from the U. S. Geological Survey, Rocky Mountain Division. VII. On the Occurrence of Topaz and Garnet in Lithophyses of Rhyolite;* by WHITMAN CROSS.

(Read before the Colorado Scientific Society, March 1, 1886.)

IN this Journal for February, 1884, I described the occurrence of minute crystals of topaz in the small drusy cavities of a coarsely crystalline rhyolite from Chalk Mountain, by Fremont's Pass, Colorado.* This was then supposed to be the first published description of the occurrence of topaz in such a manner in any eruptive rock, and especially noteworthy in one of probable Tertiary age, but it has since then transpired that the beautiful garnets and the rarer associated topaz from Nathrop, Colo., which have been sold in the mineral stores of Denver for two or three years past, present a second occurrence and that published mention of the same had already been made by J. Alden Smith in the biennial "Report on the Development of the . . . . Resources of Colorado, 1881–2," p. 36. Mr. Smith mentions a dike of an eruptive rock in the Archæan on the east bank of the Arkansas river, opposite Nathrop station on the Denver and Rio Grande R. R., Chaffee Co., and says that "a large part of it is composed of cellular pumice of a light gray color. In the cavities are beautiful crystals of topaz. . . . Associated therewith are many small dark red garnets." In the Catalogue of Minerals (l. c. p. 157) topaz is mentioned "in trachyte, near Nathrop." While I had examined many small specimens from Nathrop previous to the description of the Chalk Mountain occurrence, the gangue rock was so poorly represented by them that its nature as an eruptive rock was by no means clear, and the meager and somewhat inaccurate statements of Mr. Smith escaped attention.

Last October I had opportunity of visiting the locality at Nathrop, obtaining fuller information concerning the occurrence of the rhyolite, and a suite of specimens illustrating the same, together with the contained minerals.

Mode of occurrence of the Rhyolite.—The rock alluded to by Mr. Smith occurs directly opposite the station of Nathrop, forming a ridge about one quarter of a mile in length and 200 feet in height, running parallel to the river on its eastern bank. North of this ridge and separated from it by a stream bed is a second ridge of rhyolite, of somewhat greater extent. A third and smaller ridge of the same rock occurs on the western bank of the river, near the railroad, and in this are stone quarries now in operation. The common trend of these ridges is about

*Also in Bulletin 20, U. S. Geological Survey, 1885, p. 81.

N.W.–S.E. Nearly vertical planes of contact with gneiss are shown in one or two places, but the valley alluvium surrounds the masses for the greater part. Between the first and second ridges and east of them are more or less stratified pink or whitish rhyolitic tufa beds, containing bowlders of Archæan, rhyolite, and other eruptive rocks. This tufa is no doubt geologically connected with that occurring quite extensively among the low Archæan hills on the east bank of the Arkansas between Nathrop and Salida. The rhyolite ridges themselves seem from present appearances to be short dikes.

The Rhyolite.—The rock of the ridges mentioned varies somewhat in appearance, but cavities containing topaz and garnet are common to all, though most numerous and best developed in that mass referred to by Mr. Smith, which will therefore be first described.

The greater part of the ridge in question is made up of a white or grayish, more or less banded rhyolite, which is as a rule so compact that no constituent minerals are recognizable. The banded structure is produced by the alternation of light and darker gray layers, and is occasionally emphasized by thin bands of crystalline quartz or by an equivalent of the latter in the shape of exceedingly flattened cavities, lined by crystals of the same mineral. In this portion of the rhyolite no glass is visible, but in certain places, particularly at the south end of the dike and on its eastern side, there is a development of gray pearlite, more or less cellular and usually containing round particles of a black obsidian, somewhat larger than a pea. Whether these vitreous portions are contemporaneous with the banded rock, or represent somewhat later injections of corresponding magma, could not be definitely determined, owing to the débris-covered slopes and the limited time available for their examination. It seems most likely, however, that they are merely local phases of consolidation of the same magma as the compact banded portions.

Throughout both these types of rock are numerous cavities which in many cases represent very well the peculiar vesicles first accurately described by Von Richthofen and called by him

Lithophysen.—These are more or less round cavities, partially filled by thin curved walls, which, by a concentric arrangement and an overlapping, produce rose-like forms. In the present case these folia are often not very well developed and appear as low curved projections on the outer walls. Again, a cavity may be nearly filled by a series of concentric shells. The outer walls and the leaves of the calyx-like lithophyses are usually lined by glassy quartz crystals of minute size, with prism and pyramid. The former being clearly striated, the latter showing the hemihedral forms quite evenly balanced.

The rock of the other ridges mentioned is distinctly porphyritic in structure, showing small glassy sanidines and dark smoky quartz crystals imbedded in a predominant dull gray groundmass. Small lithophyses occur in this groundmass, sometimes exhibiting a very delicate concentric arrangement of white films, which, like those of the previously described rock, are covered by small quartz crystals.

Minerals of the cavities.—The outer walls of the lithophyses, as well as the concentric shells, when present, are primarily formed of a pure white mineral which is but seldom developed in recognizable form. Sometimes a frost-like structure caused by the interpenetration of delicate blades is seen, and quite frequently round or botryoidal masses of the white mineral occur, the surface usually showing minute crystal facets. A microscopical examination of these surfaces shows the mineral to be sanidine in stout crystals of common form. Rarely, clear crystals 1 or 2^{mm} in length are developed, and then a beautiful blue color parallel to $\frac{1}{2}^{5} \cdot \bar{\imath}$ may be detected.* In a single cavity in the porphyritic rock the feldspar assumes delicate stalactitic forms, somewhat branching at the ends and clear only at the very tips. The round feldspathic masses are often fissured in a manner clearly showing shrinkage. A silica determination upon a small quantity carefully selected, gave 66 per cent, showing that but little free quartz was included. Alumina and alkalies are also present about as in sanidine.

Upon all surfaces of feldspar, and occasionally upon garnet and topaz, are clear doubly terminated quartz crystals, often not much below 1^{mm} in length and of the form already mentioned. Although careful search has been made no tridymite has been found.

Minute opaque ore particles are very sparingly distributed through the lithophyses. Some of them are developed in tablets about $0{\cdot}5^{mm}$ across and these at least are probably to be referred to hematite. None are entirely free from dull coatings, making identification of faces difficult.

Garnet occurs in isolated crystals of a maximum diameter of about 1^{cm}, the average being $2{\cdot}5^{mm}$, of dark red color, clear and transparent, and with finely polished faces. The predominant form is that of 2–2 (211) with small facets of *i* (110). The faces of 2–2 usually show a striation parallel to the edge of *i*, due to the oscillatory combination of undetermined faces. There are also indications of another trapezohedron in which the value of *m* can be but little less than 2.

The optical properties of this garnet are anomalous. Thin sections were prepared parallel to the cube, dodecahedron and

* For fuller statements concerning this color and its cause, see Bulletin 20, U. S. Geological Survey, p. 75, 1885.

octahedron of the most suitable crystals which could be procured and the optical action seen, so far as it possesses regularity, corresponds to the observations of Klein.* The action is weak and its regularity is no doubt disturbed by the numerous inclusions of quartz at the base of all crystals.

In the porphyritic rhyolite the garnets are usually very small but perfect and possess a somewhat lighter color than in the more felsitic rock, appearing brownish red or even approaching to a cinnamon color.

In chemical composition this garnet proves to be typical *spessartite*, that is, an alumina garnet in which the lime is almost wholly replaced by manganese with some ferrous oxide. The analysis given below was made by L. G. Eakins, in the Denver laboratory of the U. S. Geological Survey. The material analyzed was of the common dark red variety from the main locality, first described, and was obtained from about 30 crystals, which were crushed and the powder carefully examined under a lens, only the transparent and perfectly pure particles being appropriated for analysis.

Sp. Gr. 4·23 at 18° C.

SiO_2	35·66
Al_2O_3	18·55
Fe_2O_3	·32
FeO	14·25
MnO	29·48
CaO	1·15
K_2O	·27
Na_2O	·21
H_2O	·44
	100·33

Topaz appears in the lithophyses of all modifications of this rhyolite, though much less abundantly than the garnet. Its crystals are prismatic, clear and transparent, either colorless, pale bluish or distinctly wine yellow, and show a fine development of all faces represented. The form is the usual one for this mineral, the faces, in order of prominence, being:

$I(110)$, $i\text{-}\frac{2}{3}(120)$, $2(221)$, $0(001)$, $2\text{-}\frac{1}{2}(021)$, $4\text{-}\frac{1}{2}(041)$, $i\text{-}\frac{1}{2}(100)$, $i\text{-}\frac{3}{2}(130)$, and $2\text{-}\frac{1}{2}(201)$.

The largest crystals which have been found (not seen by the writer), are said to have measured about one-half inch parallel to the brachy-axis, but such specimens are very rare and the average diameter is not more than one-eighth of an inch. As the prisms are attached in all positions double terminations are

*C. Klein. "Optische Studien am Granat." Nachr. v. d. k. Ges. d. Wiss. zu Göttingen, 1882, 457.

frequent. These never show any tendency to hemimorphism. The crystals occur singly as a rule, but groups are not uncommon.

In the porphyritic rock of the northern dikes the topaz occurs in very small colorless prisms, easily mistaken for quartz when not closely examined.

Concerning the color of the topaz it was noticed that nearly all of them obtained from open cavities were colorless or of the pale bluish tint, while those found on breaking open solid masses were most frequently wine-yellow. As nearly all specimens were obtained from fragments broken out by visitors, within the past two or three years, it would seem that the action of sun-light might have produced the change in color. J. Roth mentions,* while considering the changes produced in minerals by light, that von Koksharow has noted the bleaching of deep wine-yellow topaz from the Urals, to an impure bluish white, on an exposure to sun-light, of some months' duration.

Relation to other occurrences.—The Chalk Mountain occurrence, already referred to, is analogous to the present case in that the containing rock is a rhyolite and that the topaz occurs in cavities, but in detail the instances differ. In the Chalk Mountain rock the cavities are small and show no tendency to the lithophysal structure, and sanidine is the most abundant of the associated minerals, with some quartz and a little biotite.

An occurrence in Utah seems to be much more closely related to that of Nathrop. The locality was discovered by Henry Engelmann, geologist of Capt. J. H. Simpson's expedition across Utah in 1859, and is mentioned in Dana's System of Mineralogy. Engelmann states in the report of Simpson's expedition† that the topaz crystals were found loose on the surface and that they "apparently originated from one of the trachytic porphyries in that neighborhood." He did not see any in the supposed gangue and his statement, unaccompanied by any description of the rock, has naturally been overlooked or discredited.

I am indebted to Prof. J. E. Clayton of Salt Lake City, who has visited the locality in person, for information and for specimens illustrating this occurrence.‡ The locality is about forty

* Allgemeine und chemische Geologie, Bd. i, p. 42.

† Report of Explorations across the Great Basin of the Territory of Utah, etc., by Capt. J. H. Simpson, Engineer Department U. S. Army. Washington, 1876, p. 324.

‡ Another reference to this locality upon information derived from Professor Clayton has been made by Mr. G. F. Kunz in the Geological Survey publication, "Mineral Resources of the United States, 1883 and 1884," by A. Williams, Jr., in the article on Precious Stones, p. 738. The locality is first mentioned, in a very confusing manner, as if in the Pike's Peak region; the locality is wrongly stated as west of Sevier Lake; and the date of Captain Simpson's expedition is given as 1847.

miles north of Sevier Lake and nearly the same distance W.N.W. from the town of Deseret on the Sevier River. The mountain containing the topaz ("Thomas' Range" of Simpson's Report) is isolated, in an arid region. It is about six miles long from north to south, has a flat top and precipitous slopes, and consists of a white or grayish eruptive rock, an evident overflow, with indistinct banded structure and many amygdaloidal cavities in which the topaz occurs. A small fragment of the rock, sent by Prof. Clayton, seems to be a normal rhyolite. It contains small brilliant quartz and sanidine crystals lying in a dull white matrix, much resembling the common Nathrop rock. The sanidine exhibits a delicate but distinct bluish color parallel to a plane which could not be certainly determined but which no doubt corresponds to the orthodome $\frac{1}{2}\breve{5}$-$\breve{\imath}$.

The crystal forms shown by this topaz are given by Engelmann, as follows: exhibited by all I, i-$\breve{2}$, O, 4-$\breve{\imath}$, 2; by most crystals, 2-$\breve{\imath}$, 1, $\frac{1}{2}$; by a few, 4, $\bar{2}$-$\bar{\imath}$. From an examination of a few loose crystals sent me by Professor Clayton, I can add that i-$\breve{\imath}$ is sometimes developed, while O is lacking entirely in a few cases.

These crystals from Utah are larger than those from Nathrop. The base of the prisms is said to be rough and imperfect, only the ends being clear. Associated minerals have not been observed and details concerning the cavities are lacking. Nearly all crystals so far found are colorless, though pinkish, wine yellow and blue crystals have been noticed.

From various statements which have come to my notice it seems highly probable that a portion of the topaz found in different Mexican localities is also derived from eruptive rock. In no case has this been actually proven, so far as I know, by the production of specimens.

This is, it is believed, the first known occurrence of garnet in cavities of rhyolite. In the list of minerals known to occur in this manner in rhyolite J. Roth* mentions quartz, tridymite, sanidine, biotite, augite and topaz, the latter from Chalk Mountain only. To this must be added garnet and fayalite. The occurrence of the latter mineral very recently described by Iddings† from the Yellowstone National Park is very similar to that of the Nathrop minerals.

The mode of formation of the topaz and garnet is not fully determinable, but it is evident that they are not secondary products, like zeolites, but primary, and produced by sublimation or crystallization from presumably heated solutions, con-

* Allgemeine und chemische Geologie, Band ii, p. 215, 1885.

† This Journal, July, 1885, p. 58. It has also been recently observed by Tenne in obsidian from Cerro de las Navajas, Mexico. Zeitschr. d. deutschen Geol. Gesellschaft, 1885, 613.

temporaneous or nearly so with the final consolidation of the rock. The lithophysal cavities seem plainly caused by the expansive tendency of confined gases or vapors, while the shrinkage cracks in the walls and white masses of the Nathrop rock suggest the former presence of moisture. Certainly the history of the lithophyses themselves embraces that of both topaz and garnet.

Composition of the rhyolites containing topaz.—Below are submitted quantitative analyses of the only rhyolites known to contain topaz in the manner described. Under I is given the analysis of the Chalk Mountain rhyolite or nevadite, by W. F. Hillebrand; under II that of the denser Nathrop rock, and under III that of the Utah rhyolite,—both by L. G. Eakins. Analysis III was made upon the small fragment above described, which was sent me by Prof. Clayton, as typical of the occurrence.

	I.	II.	III.
SiO_2	74·45	69·89	74·49
Al_2O_3	14·72	17·94	14·51
Fe_2O_3	*none*	0·39	0·57
FeO	0.56	0·52	0·32
MnO	0·28*	0·23	*trace*
CaO	0·83	*trace*	1·03
MgO	0·37	0·14	*trace*
K_2O	4·53	4·38	4·64
Na_2O	3·97	4·21	3·79
Li_2O	*trace*	*trace*	*trace*
H_2O	0·66	2·07	0·64
P_2O_5	0·01	*trace*	
	100·38	99·77	99·99

From the above it is seen that the three topaz-bearing rhyolites agree quite remarkably in composition. They are all silica-alumina-alkali rocks, other constituents being present in almost insignificant quantities. It is however by no means a rare composition which is possessed by these rocks. The examination of the rhyolites of the Great Basin, near the 40th parallel, by the chemists of the King Survey showed several rocks closely allied to these in composition and similar ones have been described from other parts of the western United States and from Europe.

* As MnO_2 in this rock.

ART. XLII.—*On the Strain-effect of Sudden Cooling exhibited by Glass and by Steel;** by C. BARUS and V. STROUHAL.

Introductory.—In the foregoing number of the Journal we communicated a series of results on the structure of steel of a given kind, tempered hard. They showed, in general, that from the circumference to the axis of a quenched non-fileable steel cylinder, hardness continually diminishes; that the first fileable strata are encountered at a distance of about 1^{cm} below the surface. Moreover, as hardness decreases, the density of the elementary conaxial cylindrical shells increases and in proportion as the layers become more and nearly or easily fileable the density is found to approach the density of soft steel. From an examination of rods of different diameters (2^{cm} to 3^{cm}) it appears, steel of a given kind presupposed, that the hardness at a point is essentially dependent on the distance of the point below the surface. The rate at which sudden cooling takes place must be similarly conditioned. Hence it is permissible to associate the one phenomenon with the other and to state that the hardness in a given point below the surface is dependent on the rate at which cooling there takes place. This point of view is suggestive: structure investigations may be made to furnish us the best means we know for the comparison of hardness and rate of cooling.

The results cited apparently make sad havoc with physical theories of temper. They seem indeed to be fatally at variance with the usually accepted views, viz: that in hard tempered steel an abnormally dense shell is arched around an abnormally rare core, the two states of strain mutually conditioning each other. The data may even be looked upon as furnishing evidence sufficient to prove the total absence of strain. It is the object of the present paper to investigate in what measure this evidence is critically sufficient; if it be insufficient, to state the nature and relations of the strain-effect of quenching somewhat more clearly than we were able to do in our earlier work.

In our little book on the iron-carburets† we endeavored to contrast the respective merits of chemical and physical theories of temper, using for this purpose all the data known to us, as well as special results of our own. This deduction seemed warranted, that hardness and strain are distinct and separate properties of a tempered iron-carburet;‡ that they need not necessarily coexist. Leaving therefore hardness pure to be ex-

* Communicated with the permission of the Director of the Geological Survey.
† Bull. U. S. Geolog. Survey, No. 14, 1885, p. 76. ‡ Ibid., p. 103, 197.

plained chemically, we inferred that the category of electrical and magnetic phenomena exhibited by steel on passing from hard to soft are mainly referable to changes in the character and intensity of the strain which the tempered rod carries. We accepted the theory of a dense shell and rare core as being the most satisfactory and elegant conception of the strain in question,—with the proviso* that "it must be regarded as a mere *diagram* of the essential features of the vastly more complicated structure of the glass-hard rod." These conditions premised we finally interpreted all variation of strain produced by annealing as the combined effect changes of the viscosty of steel due to temperature and of interference of thermal expansion with the said strain.

The experimental question which we are endeavoring to elucidate may therefore be succinctly put as follows: 1. With what degree of sensitiveness do the variations of the density of the rod as a whole, indicate the corresponding variations of strain. 2. Is it possible successively to remove layer after layer of a rod without materially changing the character and intensity of the strain which the rod is supposed to carry. 3. In how far does the actual structure of tempered steel differ from the diagrammatic distribution of density above assumed. 4. Does the process of sudden cooling impart strain alike in kind† but differing enormously in degree to all substances. In our paper on structure we had the second and third of these points principally in mind. We were unable to obtain direct and decisive evidence of the occurrence of shrinkage during the removal of shells from a hard steel rod. But since the structure of steel differs so largely with the kind of steel operated upon we do not regard our experiments as made in sufficient number to be conclusive. An examination of the density of the elementary shells shows that the character of the density at any point regarded as a function of the distance of the point below the surface, is harmonic.‡ To investigate this relation it is unfortunately necessary to make the measurements for thin ($\frac{1}{2}^{mm}$) shells. Hence the mean amplitude of vibration and the limits of the unavoidable errors of observation are of the same order. To discriminate between the periodic effect of temper, which may show regular or irregular periodicity, and the apparently periodic distribution of mere errors of observation is difficult and requires very nice and careful observation. In the Bulletin (35) cited we attempt to arrive at this discrimination by making minute comparisons of the structures of rods of the same kind of steel, and of the same or of different diameters. This pro-

* Bull. U. S. Geol. Survey, No. 14, p. 96; ibid., pp. 95 to 98.

† We do not necessarily refer to mere volume expansion here. See Wrightson, Journ. Iron and Steel Inst., ii, 1879, p. 418. ‡ This volume, p. 386.

cedure is excessively laborious, for it calls for a detailed construction of the relation of the density and the position of the points along any given radius of the rod and subsequent examination of the properties which the divers diagrams have in common. We have gathered many data, but the work is as yet incomplete, and the reader desiring further information will have to be referred to the Bulletin, where the whole subject is discussed. Experiment on the fourth of the above topics we have now in progress and shall publish later. This narrows the purposes of this paper to the consideration of the first and most important of the above points, viz: in what degree the density of a hard steel rod at different points, even when measured with all attainable accuracy, is sufficiently sensitive to represent the character, relations and intensity of the temper-strain.

Density and Resistance (Strain) of Tempered Steel.

Experimental results.—The discussion may be appropriately commenced by an examination of the variation of density of steel successively annealed from hard to soft. Our experiments on this subject, made in some number, are detailed in Bulletin No. 27, now in press, and for this we select the following digest. The table (I) contains data for length, diameter and temper; temper being expressed by the temperature and time at which the divers glass-hard rods were annealed. The table furthermore contains the specific resistance, (s_0), at 0° C., in microhms, referred to the centimeter cube; the density (Δ_0) and the volume (ν_0) per unit of mass (g) for the same temperature, 0°. In the cases of rods Nos. I and II, density was measured in the ordinary way. The other values of Δ_0 are derived from very painstaking pycnometric measurements, all of which were made at least in duplicate and are warranted to two or three units of the third decimal. Values for resistance which could not be obtained by direct measurement were supplied by interpolation from our earlier researches. All such data are put in parentheses. Parentheses also enclose certain values for the temperature of the annealing furnace to show that they are derived by interpolation from the known power of the furnace under given circumstances. The other temperatures are measured in a way to be indicated elsewhere. The greatest care was taken to so anneal the rods as to *exclude* all errors due to superficial *oxidation or carburation.*

TABLE I.—*Electrical resistance, density and specific volume of steel, when varying with temper.*

No.	Length.	Diameter.	Temper.	s_0.	Δ_0.	∇_0.
	cm.	cm		Microhm		
I	5·3	1·9	Commercial, soft	(15)	7·8372	0·12760
			Glasshard	(44)	7·8092	0·12805
			Annealed, 100°, 1h	(39)	7·8088	0·12806
			" 100°, 4h	(37)	7·8094	0·12805
			" 100°, 8h	(36)	7·8108	0·12803
			" 100°, 12h	(36)	7·8114	0·12802
			" 200°, 30m	(28)	7·8096	0·12805
			" 330°, 5m	(21)	7·8236	0·12782
			" 620°, 5m	(18)	7·8342	0·12765
			" 805°, 30m	(17)	7·8361	0·12762
			" (1300°)	(19)	7·8465	0·12744
II	10·11	0·576	Commercial, soft	(15)	7·7033	0·12981
			Glasshard	(44)	7·6200	0·13123
			Annealed, 190°, 4m	(32)	7·6542	0·13065
			" 330°, 2m	(21)	7·6661	0·13044
			" 645°	(18)	7·7008	0·12986
			" 830°	(18)	7·7170	0·12958
			" (1300°)	(19)	7·7392	0·12922
55 to 60	21 pieces,	0·127	Commercial, soft	15·25	7·7337	0·12931
61 to 63	each about	0·127	Glasshard	43·29	7·6688	0·13040
	$2\frac{1}{2}$cm long.		Annealed, 100°, 9h	35·61	7·6976	0·12991
			" 200°, 2m	33·11	7·6981	0·12990
			" 200°, 30m	28·76	7·7030	0·12982
			" 330°, 30m	20·61	7·7215	0·12951
			" 810°, 30m	18·10	7·7872	0·12842
			" (1000°)	19·74	7·7865	0·12843
			" (1300°)	19·29	7·8007	0·12819
O	18 pieces,	0·226	Commercial, soft	(15)	7·81	0·1280
	each about		Glasshard	(44)	7·6817	0·13018
	$2\frac{1}{2}$cm long.		Annealed, 100°, 10m	(42)	7·6943	0·12997
			" 100°, 7h	(37)	7·7102	0·12970
			" 190°, 15m	(31)	7·7251	0·12945
			" 330°, 8m	(21)	7·7441	0·12913
			" 460°, 1h	18·27	7·7641	0·12880
			" 720°	17·13	7·7793	0·12854
			" (900°)	18·10	7·7840	0·12846
			" (1100°)	18·60	7·7865	0·12843
			" (1300°)	18·30	7·7856	0·12801
30 to 36	72 pieces	0·081	Commercial, soft	16·27	7·7268	0·12942
	about	0·081	Glasshard	43·86	7·6547	0·13064
	$2\frac{1}{2}$cm each.		Annealed, 100°, 1h	39·26	7·6666	0·13044
			" 100°, 13h	35·51	7·6745	0·13030
			" 190°, 4h	30·82	7·6841	0·13014
			" 190°, 4h 30m	27·10	7·6808	0·13020
	71 pieces*		" 190°, 4h 30m	27·10	7·6848	0·13030
			" 330°, 10m	20·68	7·6806	0·13020
			" 470°	18·36	7·7190	0·12955
			" 530°	18·17	7·7227	0·12949
			" 690°	17·24	7·7272	0·12941
			" 810°	17·56	7·7586	0·12889
			" 1000°	18·59	7·7705	0·12869
			" †1100°	----	----	----

* One piece lost. † Fusion of copper envelope (capsule) destroys the wire.

Discussion.—It is not our object to enter into a full discussion of these results here. We merely advert to the fact that whereas density increases continually on passing from hard to soft, resistance passes through a pronounced minimum.

Whether we regard Δ_0 as a function of s_0 or of the temperature $t°$ at which the rod was annealed, the relations contained in the table lead to an important inference, with an immediate bearing on our present purposes. It appears plainly that *the annealing of a rod successively from extreme hard to extreme soft does not exhibit the characteristics of a single and homogeneous phenomenon.* This annealing presents two distinct and independent phases which merge into each other when $t°$ corresponds to incipient redness. A graphic representation of Δ_0 varying with $t°$ shows this transition with singular clearness. Between $t=200°$ and $t=500°$, all the loci pass through two consecutive circumflexures in such a way as to change the general and pretty uniform contours of concavity downwards, into convexity downwards for the interval in question. The division of the complete phenomenon into two parts being thus suggested, we find on further inspection that the variations of the electrical constants of temper subside almost completely within the first of these parts (annealing between 0° and 350°); whereas in the second part (annealing between 350° and 1000°) they became crowded and complex. It follows plausibly and at once that during the first of the phases under consideration we encounter the subsidence of a mechanical strain. This inference gains much in weight when we find that this strain vanishes in the way peculiar to phenomena of viscosity, at a slowly decreasing rate, through infinite time.* In the second phase, mechanical and chemical occurrences are superimposed and the above results do not enable us to disentangle them.

The final important deduction from the data is this, that during the first phase in which the larger values of resistance are from two to three times the smaller values, the variation of density is slight. In the second phase we encounter large variations of density associated with small variations of resistance.

These curious relations characterize the phenomenon as a whole. We shall interpret them partially at least below.

Density and Strains in Tempered Glass.

Experimental results.—This result substantiates the evidence in favor of the existence of strain in hard steel, adduced in our earlier papers.† Beyond this it shows almost conclusively

*In other words the temper strain vanishes just like the simple "drawn" strain imparted by the wire plate, while the wires carrying them are each exposed to the prolonged action of temperature.—Bull. 14, p. 93.

†Bull. 14, pp. 88 to 103.

that the density-effect of the annealing of hard steel is out of all proportion and symmetry with the strain effect and the corresponding electrical effect. We were desirous therefore of studying the temper-strain in substances other than steel and free from carbon. Long ago, glass had suggested itself to us for this purpose.* We communicate in the following Table II the density effect produced by successive annealing of ordinary Prince Rupert drops. Twelve of these were in hand. Three were broken to test the strain, the remainder examined. All the drops contained included bubbles, one or more, often $0{\cdot}2^{cm}$ to $0{\cdot}3^{cm}$ in diameter and distributed irregularly. Usually a few large bubbles predominated. The drops moreover showed a purple coloration, which disappeared after annealing at incipient redness.† To anneal the drops at different temperatures we enclosed them in a test-tube, cushioned upon and surrounded by carded asbestos. The end of the tube was submerged sufficiently to cover the P. R. drops in boiling camphor, mercury, sulphur, etc., as given in the table. To anneal at red heat, the drops were suspended in little baskets of platinum foil, in the center of large thick clay crucible and then heated to the desired temperature in an assay furnace. Under all circumstances but one, care was taken to cool the drops slowly. Table II contains under "temper" the temperature and time of annealing, not including the time of cooling, however. The column m gives the weight of each drop in grams. Variations of m are due to accidental breakage of the frail stems of the drops. Where no such breakage occurs m is constant. Δ_0, finally, is the density of the drops at 0° C., under the conditions given. Each Δ_0 is the mean of two independent determinations and is warranted correct to within one or two units of the third place.

Table III following is constructed to facilitate a comparison of the important data. The second and third columns contain the densities of the extreme states of temper, the original quenched, "hard," and the final "soft" or thoroughly annealed state. The remaining columns contain the increments of density due to quenching, relative to the density of the soft state, the relative increments in other words which are retained at the divers temperatures given.

* Wied. Ann., vii, p. 406. 1879.

† The color of the drops is amethystine; the powdered glass pink.

TABLE II.—*Temper, weight and density of quenched glass (Prince Rupert's drops), successively annealed.*

No.	TEMPER.	*m.*	Δ_0	REMARKS.
		g.		
1	Quenched	1·3500	2·4345	Bubbles. Color.
	Annealed, 360°, 30^m (Mercury.)	1·3500	2·4401	Do.
	Annealed (650°), 10^m	1·3497	2·4901	Bubbles and color vanish. Form of drop not changed. Cooled slowly.
	Annealed, red heat	1·3470	2·4910	Cooled slowly.
	Annealed, red heat	1·3311	2·4883	Cooled *in air*, from intense redness.
	Annealed, red heat	1·3312	2·4915	Cooled slowly.
2	Quenched	1·3200	2·4364	Bubbles. Color.
	Annealed, 360°, 30^m (Mercury.)	1·3200	2·4408	Do.
	Annealed (650°), 10^m	1·3191	2·4903	Bubbles and color vanish. Form of drop not changed. Cooled slowly.
	Annealed, red heat	1·3172	2·4912	Cooled slowly.
3	Quenched	1·4590	2·4374	Bubbles. Color.
	Annealed, 200°, 15^m (Paraffine.)	1·4591	2·4364	Do.
	Annealed, 360°, 30^m (Mercury.)	1·4590	2.4411	Do.
4	Quenched	1·3305	2·4356	Bubbles. Color.
	Annealed, 200°, 15^m (Paraffine.)	1·3305	2·4351	Do.
	Annealed, 360°, 30^m	1·3292	2·4383	Do.
5	Quenched	1·3009	2·4349	Bubbles. Color.
	Annealed,* 200° 1^h 30^m (Camphor.)	1·3009	2·4359	Do.
	Annealed, 360°, 1^h (Mercury.)	1·3010	2·4402	Do.
	Annealed, 450°, 30^m (Sulphur.)	1·3012	2·4446	Do.
	Annealed (550°), 10^m	1·2983	2·4531	Color vanishes. Cooled slowly.
	Annealed, red heat	1·2982	2·4914	Bubbles gone. Form partially changed.
6	Quenched	1·4409	2·4323	Bubbles. Color.
	Annealed,* 200°, 1^h 30^m (Camphor.)	1·4409	2·4333	Do.
	Annealed, 360°, 1^h (Mercury.)	1·4409	2·4382	Do.
	Annealed, 450°, 30^m (Sulphur.)	1·4412	2·4422	Do.
	Annealed (550°), 10^m	1·4410	2·4534	Color vanishes. Cooled slowly.
	Annealed, red heat	1·4408	2·4893	Bubbles gone. Form partially changed. Slow cooling.
7	Quenched	1·4795	2·4395	Bubbles. Color.

* An explosion of the camphor vapor may have slightly raised these values, but we believe them to be correct.

No.	Temper.	m.	Δ_0	Remarks.
8	Quenched	1·0025	2·4395	Bubbles. Color.
	Annealed, 360°, 30^m (Mercury.)	1·0025	2·4444	Do.
	Annealed, 360°, 3^h (Mercury.)	1·0023	2·4482	Do.
	Annealed, 450°, 1^h (Sulphur.)	1·0023	2·4526	Do.
	Annealed, 450°, 4^h (Sulphur.)	1·0023	2·4586	Do.
	Annealed, red heat	0.9982	2·4901	Bubbles and color gone. Form partially changed. Cooled slowly.
9	Quenched	1·2759	2·4365	Bubbles. Color.
	Annealed, 360°, 30^m (Mercury.)	1·2745	2·4423	Do.
	Annealed, 360°, 3^h	1·2745	2·4436	Do.
	Annealed, 450°, 1^h	1·2745	2·4472	Do.
	Annealed, 450°, 4^h	1·2727	2·4510	Do.
	Annealed, red heat	1·1592	2·4929	Bubbles and color gone. Form partially changed. Cooled slowly.

Table III.—*Density of Prince Rupert's Drops, Quenched and Annealed. Digest.*

No.	Hard. Δ_0.	"Soft." Δ_0.	Density-increment relative to "soft," when annealed at						
			20°	200°	360°	450°	(550°)	(650°)	Red heat.
			−0·0	−0·0	−0·0	−0·0	−0·0	−0·0	
1	2·4345	2·4915	229	----	207	----	----	006	−0·0002
2	2·4364	2·4912	222	----	202	----	----	004	−0·0000
3	2·4374	-----	216	220	201	----	----	----	------
4	2·4356	-----	223	225	212	----	----	----	------
5	2·4349	2·4914	227·	223	206	188	154	----	−0·0001
6	2·4323	2·4893	229	225	205	189	144	----	+0·0007
7	2·4395	-----	207	----	----	----	----	----	------
8	2·4395	2·4901	203	----	184 168	150 127	----	----	+0·0004
9	2·4365	2·4929	227	----	203 198	184 168	----	----	−0·0007

Discussion.—The salient features of these data are obvious from an inspection of Table III. The density-effect of quenching is decidedly *negative;* the increase of specific volume is exceptionally large. Moreover, the nine Prince Rupert drops examined exhibit nearly the same initial density, and nearly the same final density. The approximate equality of the values Δ_0 for the soft state is easily explained. They indicate that in proportion as we bring the strain to vanish, we reach the normal density of the glass. Not so easy is it to account for the observation, that the density of the Prince Rupert drops shows almost the same degree of equality in the hard (quenched) state. Indeed, if we take the fact into consideration that the drops invariably contain *bubbles* distributed irregularly and without apparent relation as regards size and number, the difficulties of explanation are increased. In other words the remarkable result that the volume-increase due to quenching is quite as much the same for all drops as is at all possible for the case of so complicated an operation, is an exceedingly striking and important result and leads to this inference: Inasmuch as bubbles are present in like total volume in each of the drops, their presence can not be a circumstance of mere accident; they must be regarded as a normal effect or, better, a necessary result of the operation of quenching applied to glass; they must in some very intimate way be connected with the strain which the glass globules have experienced in virtue of sudden cooling.

Retaining this very plausible surmise in mind, we proceed to a more minute inspection of the effect of annealing the hard Prince Rupert drops. We obtain results very similar to those investigated above for steel. The density effect of annealing is decidedly positive, and is greater as temperature and time of exposure are increased. Again, we readily divide the physical effect of annealing into two parts or phases. The first of these corresponds to the annealing temperatures 0° to 500°, the other to higher temperatures. The range of temperatures corresponding to the first phase is therefore larger for glass than for steel; and if we compare Tables I and II it appears obviously, that for like density effects the annealing temperatures must be chosen higher in the former case (glass) than in the latter. But the change of density encountered in both instances is small; and yet in spite of the small density-effect during the inferior stage of annealing, by far the greater intensity of strain vanishes. The drops after annealing at 200° are still explosive; if they be broken after having been annealed in boiling sulphur (450)° they are found to have lost all traces of the explosive properties which the originally quenched drops possessed.

Professor Rood* informed us that the polarization figures could be quite wiped out by annealing such ordinary glass as exhibited them only as far as the temperature of melting zinc. We infer that at the end of the first phase of annealing we have in hand a hollow glass globule practically free from strain.

During the second phase of the annealing phenomenon (500° to 1000°), we observe a very pronounced change of the density of the Prince Rupert drops, corresponding to the above result for steel. But the explanation is here readily at hand: at incipient redness the enclosed bubbles *disappear* or are reduced to mere specks. The large increment of density in question is therefore nothing more than an expression for the collapse of the viscous hollow globule in virtue of atmospheric pressure. This important observation enables us to interpret all the phenomena of annealing satisfactorily. It must therefore be carefully examined.

We will endeavor to prove that the bubbles are vacua; that they are not accidental inclusions of gas or aqueous vapor. The temperature from which glass is quenched is certainly less than 1500°. The temperature at which glass is sufficiently viscous to yield easily to atmospheric pressure is certainly greater than 500°. Suppose now that the changes of volume of the bubble were the result of thermal expansion of an included gas. Let v_{1500} and v_{500} be the volumes of the gaseous inclusion at 1500° and 500°, respectively, under normal pressure. Let v_h and v_s be the volumes of the (gas) bubble for the quenched-hard and annealed-soft states. Then we deduce, *a fortiori*,

$$\frac{v_h}{v_s} < \frac{v_{1500}}{v_{500}} = 2{\cdot}3 \qquad (1)$$

with this as a point of departure the following little digest, Table IV, of mean results has been prepared. Here m is the mean mass of all the drops examined; Δ_h, Δ_s, V_h, V_s, their mean density and total volume for the hard and the soft states, respectively; v is the mean volume, r the equivalent mean radius of the bubbles. In the second horizontal row V_h has been diminished one-half per cent to refer all volumes to the beginning and end of the second phase of annealing.

* Results obtained by Professor Rood during his experiments with high vacua.

TABLE IV.—*Mean volume relations of the Prince Rupert drops and of the hypothetical gas-bubble.*

V_h	V_s	v at 1500°	v at 500°	r at 1500°	r at 500°	
cc.	*cc.*	*cc.*	*cc.*	*c.*	*c.*	
0·5454	0·5334	0·0120	0·0052	0·142	0·107	$\frac{v_h}{v_s} < 2{\cdot}3$
0·5427	0·5334	0·0093	0·0041	0·130	0·099	$\frac{r_h}{r_s} < 1{\cdot}3$

Mean $m = 1{\cdot}3288$ g
"Hard:" Mean $\Delta_h = 2{\cdot}4363 \pm 0{\cdot}0008$
"Soft:" Mean $\Delta_s = 2{\cdot}4911 \pm 0{\cdot}0016$

Inasmuch as the values v_{500} and r_{500} are inferior limits, it is clear that if the bubbles were gas or vapor, they would be of the same order of visibility before and after annealing. In other words, if the bubbles were gas, casual inspection would not detect a difference of their size in the hard-quenched and in the "soft" drops. In the experiments, however, the bubbles all but vanish. Hence they can not be gas.

To obtain additional assurance on this point we ground flat faces on the annealed drops, Nos. 1, 5 and 8, and then measured the size of the inclusions. We found these values:

No. 1: $v_s = 0{\cdot}000037$ c. c.
No. 5: $v_s = 0{\cdot}000062$ c. c.
No. 8: $v_s = 0.000040$ c. c.
Mean: $v_s = 0{\cdot}000046$ c. c.

From actual measurement therefore we find,

$$\frac{v_h}{v_s} > 100 \qquad (2)$$

a result wholly incompatible with $\frac{v_h}{v_s} < 2{\cdot}4$ as derived above (Table IV). It follows conclusively that the bubbles are not accidental gas inclusions; that only an insignificant part of the variations of volume produced by quenching can be referred to thermal expansion of gas.

If the gas were aqueous vapor, and if dissociation were complete, then the upper limit of (1) would have to be increased in the ratio of 3 : 2. This does not remove the discrepancy between (1) and (2). Moreover, since dissociation of water is only incipient at 1500° and is not even complete at the temperature of melting platinum, the volume variation of the bubbles can not be due to the presence of water in the bubbles.

If on the other hand we endeavor to explain the bubbles as vacuities* left by the contracting glass, we arrive at accordant and plausible results. Let t be the temperature to which the

* Very analogous to Torricellian vacua.

homogeneous glass drop must be heated in order that the observed mean volume of the soft state may be equal to the observed mean volume of the hard state. Then

$$t < \frac{1}{3\alpha} \frac{\Delta_0 - \Delta_t}{\Delta_t} \qquad (3)$$

where α is the ordinary coefficient of linear expansion of glass. By inserting the values of Table III into (3) we derive

$$t < 900°.$$

In other words the quenched globule has retained the volume which the hot glass possessed at a temperature certainly smaller than 900°. This result taken together with the other is conclusive.

The general result of our investigation on the process of sudden cooling, therefore, points out the fundamental importance of a rigid shell. As the material (glass or steel) cools, contraction as a whole takes place not centripetally but centrifugally, i. e., not towards the center of figure but away from it. So long as the interior remains liquid or viscous, the result is simple separation, commencing at points where minute air bubbles may preëxist,* rather than at points of the continuity of glass. The final result is a vacuum bubble such as we have observed it. In proportion as the interior becomes rigid, the temper strain appears. Should the glass hold gases in solution, they would tend to escape into the vacua in question. There is probably another reason why in most instances the bubbles cannot be brought completely to vanish.

Annealing reverses the whole phenomenon. The small changes of density observed in the first phase may be easily accounted for; it is probable that during these stages of annealing the re-arrangement of molecules and disappearance of strain is accompanied by expansion inward, toward the vacua. Hence the incommensurately small variation of mean density which accompanies the great optical effects (glass), and the great electrical effects (steel).† During the second stage of annealing, again, the density-effect is incommensurately large; for glass it is the expression of a mere collapse due to atmospheric pressure. At all events the density-effect (error) due to bubbles quite swallows up the density-effect due to strain. Hence to represent the true relation of density and resistance or of density and annealing temperature in case of steel, it may be necessary to lower the part of the curves corresponding to the second place of annealing by amounts equivalent to the bubble

* P. R. drop No. 1, heated intensely in a blast lamp and cooled in air shows a decrement of density. This is due to the rapid cooling. For when this drop is heated and cooled in the crucible, density is again incremented. The experiment shows the tendency of glass to retain strains. During the heating to 1000° no expansion of the very small bubbles was observable.

† The electrical and optical criteria may be considered equally sensitive.

or fissure discrepancy, or else for like reasons to raise the parts of the curves corresponding to the first phase. If this be done the circumflexures become less pronounced or disappear, and the points for the commercial soft state are more easily referred to the curves to which they belong. If, therefore, allowance be made for the distortion due to internal sensible pores, the relations become more uniform.

It is interesting to observe that glass retains the volume-expansion corresponding to a temperature somewhat below 900°; whereas steel retains the volume-expansion of a temperature below 400°. Similarly the strain in steel is very perceptibly affected by annealing temperatures as low as 50°, whereas for glass the perceptible annealing effects are only incipient even at 200°. The amount of strain retained is, *cæt. par.*, not merely a function of the viscosity of the material subjected to quenching. It must depend also on the heat conductivity of this substance. For instance, if like figures of glass and of steel be quenched alike, then at the same time and depth the thermal gradient would be much steeper in the case of glass than in the case of steel. Hence, *cæt. par.*, during quenching a rigid shell is possible in the case of glass for higher temperatures of the core than in the case of steel. The sudden contraction of the shell pressure has a marked effect on the melting point or degree of fluidity of the core. But it is best to waive this observation here, for the want of data to interpret it.

We have finally to consider the bearing of the results of this paper on the structure of steel. The detailed similarity observed in the annealing of glass and of steel suggest the inference that the interior of hard steel may be sensibly fissured. Under all circumstances the diagrammatic structure of dense shell and rare core would be inaccurate to the extent in which these fissures are irregularly distributed. Hence the difficulty of developing the true character of the dependence of the density (δ) at any point upon the distance of this point below the surface. We are able to account in part for the quasi-harmonic relations obtained both by Dr. Fromme* and by ourselves.† While the consecutive shells are being removed by solution, periodic fluctuation of δ must result whenever fissures are invaded. If, furthermore, we take into consideration that the density effect of even great intensities of temper-strain is small, it appears that the true nature of the strained structure of tempered steel may be beyond the discernment of the density-method of investigation, altogether. The *gross* variation of density along the radius is a carburation phenomenon.

Retrospective.

In our earlier work on steel we adverted to the singular co-

* Wied. Ann., viii, p. 356, 1879. † Bull. 35. This volume, p. 386.

incidence of the resistance increments corresponding to like volume increments, no matter whether the latter be the result of temper or of temperature. The light which the new data throw upon the internal condition of tempered steel—the tendency to a fissured structure—shows, however, that this material is not as well adapted for the quantitative evaluation of the *true* relation between volume and resistance, as we supposed. So long, moreover, as the meaning of the minimum resistance and of certain carburation phenomena encountered during annealing at red heat remains obscure, it is safest to give the said relations no more than qualitative importance. The best means to the end in question is probably to be sought for in the compression of mercury.

With this unimportant exception, the present results have materially substantiated our earlier views at every essential point. Hence we infer as before that "the annealing of steel, considered physically, is at once referable to the category of viscous phenomena. In the ordinary cases of viscosity measurements, the phenomenon is evoked by sudden application of stress (torsion, flexure, tension, volume-compression, etc.) under conditions of constant viscosity; in the case of annealing by sudden decrease of viscosity under conditions of initially constant stress. Thermal expansion interferes with the purity of these phenomena by destroying the conditions of existence of the strain which accompanies hardness, and this in proportion as the expansion is greater."* Again, irrespective of the manifestation of mere hardness, "the existence of the characteristic strain in glass-hard steel is the cause of electrical effects so enormous, that such additional effects which any change of carburation may involve may be disregarded and the electrical and magnetic results interpreted as due to variations in the intensity of the said strain."†

This deduction applies of course to the first phase of the phenomena of annealing, since it is within these limits that the strain in question is brought to vanish. With these results in hand we may proceed justifiably toward a study of the question, whether the conditions for the permanent retention of magnetism in an iron-carburet are not the identical conditions for the permanent retention of any strain. If we select the temper-strain for comparison, we do it not merely because our experience has familiarized us with this strain, but because of the clear-cut beauty of its manifestations, and because of the simplicity and pronounced character of the functions which describe it.‡

Washington—Prague, April, 1886.

* Bulletin, U. S. Geolog. Survey, No. 14, p. 196. † Ibid., p. 97.

‡ We desire to remark that the principal inferences of this paper have since been substantiated by polariscopic evidence, and by an investigation of the density of the consecutive shells of the P. R. drop. These results will be given in our next paper, nearly ready. May, 1886.

ART. XLIII.—*Upon the Origin of the Mica-Schists and Black Mica-Slates of the Penokee-Gogebic Iron-Bearing Series;* by C. R. VAN HISE.

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THE iron-bearing formation of the Penokee-Gogebic region has been traced from Lake Numakagon in Wisconsin to Lake Gogebic in Michigan, a distance of more than 80 miles. The rock belts of this series traverse the country in a general east-and-west direction. They dip quite uniformly to the northward at an angle usually ranging from 60° to 70°, though occasionally the dip is at a lower angle. They lie unconformably upon a series of schists, gneisses and granites, and are overlain unconformably by the Keweenaw Series.†

At Penokee Gap, Wisconsin, the series is, in round numbers, 13,000 feet thick, of which the upper 11,000 feet are mica-schists and black slates,‡ which thickness is retained to the eastward until Michigan is reached. These upper members have been traced continuously from English Lake (chiefly in Secs. 5 and 8, T. 44 N., R. 3 W., Wis.) to the Black River (Sec. 12, T. 47 N., R. 46 W., Mich.), a distance of more than 40 miles, their course in this distance being north of east, in places as much as 30° north of east (see map).§

The present lithological condition of the upper members of the formation is quite diverse in different localities. The group comprises fine-grained, crystalline mica-schists, black mica-slates, greywackes,‖ greywacke-slates and quartzites. The exposures at the eastern extremity of the belt at Black River are red and white feldspathic quartzites. As we proceed westward the exposures found show chloritic greywackes and greywacke-slates. In section 14, T. 46 N., R. 2 E., Wis., the exposures

* In advance of a full treatment of the subject to be included in a memoir on the Penokee-Gogebic Iron-Bearing Series, by R. D. Irving and C. R. Van Hise.

† This Journal, March, 1885. Divisibility of the Archæan in the Northwest, by R. D. Irving.

‡ Geol. Wis., vol. iii, p 105.

§ The accompanying map is taken from the article before referred to. For discussion of stratigraphical relations and geographical distribution of the Penokee-Gogebic Series, see the same article, also Geol. Wis., vol. iii, pp. 100–166.

‖ The term greywacke is here used in a lithological sense, in accordance with the definition of the term given by Geikie, Text Book of Geology, 2d ed., p. 162: "A compact aggregate of rounded or subangular grains of quartz, feldspar, slate, or other minerals, or rocks, cemented by a paste which is usually siliceous, but may be argillaceous, feldspathic, calcareous or anthracitic. Gray, as its name denotes, is its prevailing color; but it passes into brown, brownish purple, and sometimes, where anthracite predominates, into black. The rock is distinguished from ordinary sandstone by its darker hue, its hardness, the variety of its component grains, and above all by the compact cement in which the grains are imbedded."

show biotitic and chloritic greywackes. Continuing westward, the rocks become more and more micaceous, and at Penokee Gap, Wisconsin, they are mostly mica-schists and black mica-slates, although narrow belts of micaceous greywacke are yet found; while the schists at English Lake taken by themselves would probably be considered completely crystalline rocks—as completely crystalline as some mica-schists in the older gneissic formation. These rocks, at present of such widely varying character, microscopic study shows to have been originally in essentially the same condition. All were once, as some are still, completely fragmental rocks composed chiefly of quartz and feldspar, mingled in places with a little clayey matter, perhaps also with a small quantity of fragmental mica and some ferrite. The fragmental feldspar is or was very largely orthoclase, although plagioclase is usually, and in certain localities quite plentifully, found. Measurements of its extinction angles show this plagioclase to be of an acidic character, and it is probably in great part oligoclase. The proportions and magnitudes of the fragments of quartz and feldspar vary in different localities. The quantity of feldspar was apparently considerably greater in the rocks of the western part of the area than in those of the eastern part, i. e., was greater in those rocks which are now mica-schists and mica-slates than in those which have formed the kinds to which the name greywacke is here applied.

As far as the quartzites, greywackes and greywacke-slates are concerned the microscope shows that they reached their present conditions by processes already fully described by Irving and myself.* Briefly summarized, these processes included: secondary enlargement of the quartz fragments and in a few cases apparently of the feldspar fragments also; the deposition or formation *in situ* of interstitial finely crystallized quartz; and a chloritic replacement of the feldspars, with consequent separation of silica. In general, the processes by which the mica-schists and black slates have reached their present condition are much the same as the above, with the very important difference that the feldspars instead of altering to chlorite have altered to muscovite and biotite—chiefly the latter—with an accompanying separation of silica;† *the result being the production, from a completely fragmental rock, by metasomatic changes only, of a rock which presents every appearance of complete original crystallization, and which would be ordinarily classed as a genuine crystalline schist.*

* Bulletin U. S. Geol. Survey, No. 8.

† Lehmann in his work on the "Entstehung der altkrystallinischen Schiefergesteine," demonstrates the formation of abundant secondary biotite and other minerals as accompanying metamorphoses by folding. His work does not state, however, exactly how the biotite developed.

It is important here to recall the chemical changes which occur in the alteration of orthoclase and oligoclase to chlorite, muscovite and biotite. The average content of silica of the following minerals is taken from Dana's System of Mineralogy: orthoclase, 65 per cent; oligoclase, 62 per cent; muscovite, 45 per cent; biotite, 40 per cent; chlorite, 25 to 30 per cent. Evidently where the alterations of orthoclase and oligoclase to muscovite, biotite, and chlorite have taken place so extensively as in the rocks under discussion, it is not difficult to explain the presence of the silica which has enlarged the fragments of quartz, replaced those of feldspar, and separated as independent interstitial quartz. One of these alterations is stated by Tschermak * to occur as follows: "Wenn man die dreifache Formel des Feldspathes $3(K_2O . Al_2O_3 . 6SiO_2)$ mit jener des daraus entstandenen Glimmers $K_2O . Al_2O_3 . 2SiO_2 + 2(H_2O . Al_2O_3 . 2SiO_2)$ vergleicht, so eigibt sich, dass von der ursprünglichen Menge $6SiO_2$ nur $2SiO_2$ in die neue Verbindung übergehen und $4SiO_2$ übrig bleiben." In farther speaking of the alteration of orthoclase to muscovite, Tschermak also observes: "Der neu enstandene Muscovit ist öfters auch von Biotit (Magnesiaglimmer) begleitet."

For the iron of the biotite in the rocks under consideration, it is not difficult to account. Pyrite, marcasite and ferrite are quite widely present in these rocks as accessory constituents. Often the relations of the pyrite or marcasite and biotite (folia of the latter surrounding particles of the former) is such as to lead to the supposition that the former minerals have furnished the iron necessary for the transformation from feldspar to biotite. At all events they indicate a quite sufficient supply of iron.

For a part at least of the magnesium of the biotite, it seems that we must look to some source extraneous to the feldspar fragments; i. e., we must regard it as having been supplied by percolating waters. That calcium-bearing and magnesium-bearing waters have been present in these rocks is evident from the occasional presence of secondary calcite and dolomite. The case is the same as that presented by the replacement of feldspar by chlorite, which has commonly taken place in the greywackes of this and other regions in the Lake Superior country. Analyses of three of the biotite-schists gave an average content of MgO of 2·22 per cent, which if entirely contained in the biotite would correspond to a probable proportion of that mineral of from 10 to 20 per cent.

The change from fragmental quartz-feldspar rocks to quartzites and greywackes in this belt having been produced by metasomatic changes, as indicated above, there is a strong presumption that the mica-schists and slates are of the same origin;

* Lehrbuch der Mineralogie, Zweite Auflage, page 462.

a presumption which is rendered stronger by the fact that in passing from east to west along the belt the biotite first appears in minute quantities, becomes gradually more plentiful until it equals in quantity the chlorite and farther west grows still more abundant, until, at English Lake, little or no chlorite is found and we have a typical mica-schist.

In the detailed descriptions below given of these micaceous rocks, I begin with one not greatly different from its original condition, and proceed toward those which are more and more completely crystalline. There is a considerable interval as to degree of alteration between each description and the succeeding one, but the gaps cannot be made shorter without unduly extending this paper. In a study of all the sections of the group, some sixty in number, these intervals are closed.

(1.) *Muscovitic and Biotitic Greywacke.*—Macroscopically this rock is gray-colored, medium-grained, and massive. It breaks with a conchoidal fracture. Under the microscope large fragments of quartz and feldspar, with the alteration-products and replacement products of the latter, compose the rock. The grains of quartz are enlarged and consequently minutely angular, although still retaining their general roundish forms. Much of the feldspar is quite fresh, many individuals showing no alteration further than a slight kaolinization. Other feldspar fragments, however, include each many grains of quartz, or a single large, reticulating quartz individual and numerous flakes of muscovite and biotite. Here the quartz, muscovite and biotite are plainly replacements and alteration-products of the feldspar. In some cases this alteration has proceeded so far as to leave but irregular, partly replaced and altered cores of feldspar which are entirely surrounded with the secondary quartz, muscovite and biotite. Again, in other places, the original rounded outlines of the feldspars are distinct, the replacements and alterations having occurred in spots through the grains. The finer-grained parts of the rock are composed of quartz, a portion of which is clastic; of feldspar—the proportion being smaller than in the coarser parts; and of biotite and muscovite. The mica is here clearly also, to a very large extent, secondary to feldspar, while there is little doubt that the small remaining fraction of the mica is of the same origin. Scattered through the finer portions of the section are numerous small particles of a black substance which is taken to be partly altered pyrite or marcasite, and perhaps also partly carbonaceous material.

(2.) *Biotitic Greywacke.*—Macroscopically this rock differs from (1) only in being of a darker gray color; and under the microscope also it is much the same except that the micaceous alteration of the feldspars has been carried farther. Well rounded fragments of quartz and feldspar with the secondary

products of the latter compose most of the section. A few of the grains of quartz are finely complex, and nearly all of them are enlarged by renewed growths. The alteration of feldspar to biotite is nicely shown. The freshest of the feldspar grains are surrounded by and more or less deeply penetrated by secondary biotite. These grains yet retain their well-rounded forms. However, in many cases, the original outlines of the grains of feldspar are lost. Often the entire surfaces of the feldspars include very numerous particles of the biotite, there remaining through such areas, here and there, little spots of feldspar which act as a unit in each area. With a low power such areas appear to be roundish aggregates of biotite. It is only with a higher power that the remaining feldspar and its true relations to the biotite are discovered. The rather sparse matrix of the rock does not differ materially from the matrix of (1).

(3.) *Biotite-schist.*—Macroscopically this rock is mottled dark-gray and black, fine-grained, and quite massive, showing roundish cleavage-areas. Under the microscope the cleavage-areas seen macroscopically are found to be well-rounded, partly-altered feldspars. These feldspars are set in a ground-mass which consists of intimately mingled grains of quartz and small brown folia of biotite with a considerable quantity of ferrite. The partial decomposition of the feldspar has resulted in the formation of very numerous small folia of biotite and a few larger ones of muscovite. In places also the feldspar is replaced by quartz. In each of the feldspar areas the secondary mica is found most plentifully at or near the exteriors of the grains, although in almost every case the alteration has proceeded to a greater or less degree quite to the center. In the matrix of the rock it is quite impossible to determine what part, if any, of the quartz is fragmental. The biotite of the matrix is in part plainly secondary to feldspar and is precisely like that found in the larger feldspars. The folia are deep brown and very strongly dichroic, and therefore probably bear a large percentage of iron. The feldspar plainly shows this rock to have been fragmental, and the alteration of feldspar to both biotite and muscovite upon a large scale is most beautifully shown. The large quantity of dark brown and black ferrite has doubtless furnished the iron required for the formation of the biotite. The peculiar spotted appearance of the section, viewed without the microscope, gives a clear idea, when taken in connection with its appearance under the microscope, of the processes by which the rock reached its present condition.

(4.) *Muscovitic Biotite-Schist.*—Macroscopically this rock is very fine-grained, grayish and quartzose, with very fine mica flakes visible. Under the microscope the thin section shows a fine grained ground-mass of quartz and feldspar in which are

abundant muscovite and biotite. Many of the large quartz grains include numerous folia of mica. The feldspar areas include quartz and both muscovite and biotite. This section, by itself, if not examined closely would be taken to be of a completely crystalline mica-schist in which the interlocking and mutual inclusions of the different minerals are of the most intricate kind. But, like the other mica-schists of the Penokee series, it is an ordinary clastic rock in which the metasomatic changes have gone very far. The large areas of quartz, including folia of mica, are in the places of feldspar fragments. As the feldspar has altered to mica the excess of silica has separated as quartz. Frequently the alteration of a single feldspar has resulted in the formation of a single ramifying individual of quartz, with several or many included folia of mica, mingled with which are detached remnants of the feldspar. In other cases the decomposition of a feldspar has resulted in the formation of many grains of quartz as well as numerous folia of mica. In yet other cases the feldspar areas have not altered to such extent as described above. In almost every case the rounded exteriors of the clastic grains are lost, but irregular areas of considerable size often remain considerable, which include but few folia of biotite or little replacing quartz, or both.

(5.) *Muscovitic Biotite-Schist.*—Macroscopically this rock is fine-grained to aphanitic, and dark grayish black, with rather distinct lamination. Under the microscope the sections show a rather fine-grained, apparently completely crystalline, typical mica schist. The ground-mass consists chiefly of quartz, mingled with which is feldspar, both orthoclase and plagioclase. Biotite in rather small, well-defined folia of quite uniform size is very plentiful. Muscovite is much less abundant. That all the mica is a secondary product cannot be proved from the sections from this locality taken by themselves. A portion of it is, however, certainly of this nature. Many grains of feldspar are partly surrounded and cut by folia of mica, while many of the larger particles of feldspar contain throughout their areas numerous folia of mica which in magnitude and appearance are exactly like the mass of the biotite in the rock. Quite numerous black grains and crystals of a mineral which is taken to be pyrite are seen, which are included alike in the quartz, feldspar and mica.

The rocks above described thus furnish us with a graded series, from the slightly altered greywackes to the crystalline mica-schists. There are many similar mica-schists in other parts of the Lake Superior region which there is good reason to think have had a similar origin; but those wide-spread mica-schists associated with the older gneisses are not now referred to.

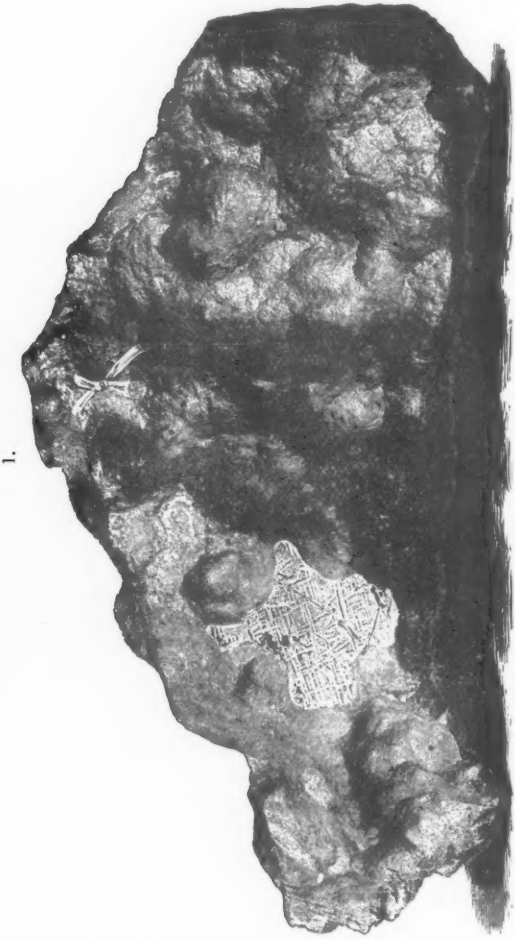
The micaceous alteration of feldspars has also been very important in the production of various black mica-slates of the Penokee series. Macroscopically these slates are all exceedingly fine-grained and finely laminated, cleaving readily along the planes of lamination. In color they vary from dark gray to black. A lens shows many of them to contain numerous small particles of pyrite. Very numerous roundish black areas are contained in the fine-grained, gray material in many of the specimens. These areas in some cases show distinct cleavage surfaces and are taken to be large fragmental particles. In other cases they are dull and break without giving cleavage surfaces, while in yet other specimens these darker spots are not found at all.

Under the microscope the rocks which have the mottled appearance described above consist of two parts, a finely crystalline matrix, and coarse, well rounded fragmental feldspars, which are always altered to a greater or less extent. This alteration is to biotite and quartz, many small folia of biotite and grains of quartz always being found in a single feldspar individual. Every gradation of this change is seen, from grains of feldspar which contain but little biotite and quartz to those in which the remaining feldspar is just sufficient in quantity to enable one to perceive that the detached particles are parts of a common individual. Doubtless also the alteration to biotite and quartz has often been carried out completely. Accompanying the biotite thus secondary to the feldspar, is much black, opaque, partly-altered pyrite in minute particles. The black, roundish spots seen macroscopically are evidently the partly-altered feldspar fragments. The degree of this alteration as determined by microscopic study corresponds exactly with the appearance of the rock as seen in the various hand-specimens. In the specimens in which the feldspar areas are well outlined and show clearly marked cleavage surfaces, the biotitic and quartzose alteration has taken place to but a small extent. In the specimens in which the feldspars are obscurely outlined and which lack cleavage the alteration has extended very far. The matrices of these rocks and the sections of those not containing large grains of feldspar are composed of intimately mingled quartz. feldspar, biotite and pyrite, with perhaps a little organic matter.* A portion of the quartz is certainly fragmental, as is evidenced by a secondary enlargement. The biotite is all believed to be due to the alteration of feldspar, much of it certainly being of this nature. The matrices of the different sections vary in coarseness and in the relative proportions of the various mineral constituents, but are alike in all essential points.

* Geol. Wis., vol. iii, p. 136.

ART. XLIV.—*On two masses of Meteoric Iron, of unusual interest;* by WM. EARL HIDDEN.

IN late years the discovery of masses of meteoric iron has been of frequent occurrence, and it has become almost un-



The Independence County, Arkansas, Meteoric Iron.
Weight ninety-four pounds.
(ONE-THIRD NATURAL SIZE.)

necessary to give figures of them, unless of rare form or of unusual composition, because of their great similarity. The masses here described were not seen to fall, but were discovered

in the surface soil, and thus their history is incomplete. These two meteoric irons are, however, unusual in several of their characteristics and the writer has concluded to describe them and give them careful illustration.

Both of these masses came into the writer's possession at nearly the same time and from the same indirect source, and he hence describes them together. They were both on exhibition at the World's Industrial and Cotton Centennial Exposition in New Orleans, where they first came under his personal notice, and later into his possession. They were received in Newark, N. J., last June, at the close of the Exposition, since which time several notices of them have appeared in the local press and in other publications.

The larger mass, the one from Arkansas, will be noticed first. Figure 1 gives a fair idea of its exterior appearance.

1. The Independence County, Arkansas, Meteorite.

The following extracts from a letter from Mr. John Hindman of Elmo, Ark., dated July 2nd, 1885, sets forth the manner and time of its discovery.

"This meteor was found about the last of June, 1884, by my stepson George W. Price, on a mountain known as the 'Joe Wright Mt.,' a small eminence situated about seven miles east of Batesville (Independence County, Arkansas). The soil there was cut into deep gullies, which, farther down the mountain side converged into one. It was where these gullies met that the meteor was found. The town of Sulphur Rock is about three miles distant, southwest, from the place of the discovery."

The weight of the mass is ninety-four pounds. It is seventeen inches long and eight inches thick in its greatest diameter. Its surface is pitted with ovoid depressions of various sizes, which lie with their longer axes in nearly the same general direction. The exterior was almost black in color and looked blistered. No rusty appearance or alteration from oxidation was noticed on any part, which would go far to prove that this mass had not long been on the earth. Its size is unusual, yet several masses described within the past two years exceed it in this respect. Its most interesting feature is the presence of a hole through it, near the edge, measuring five-eighths of an inch in diameter at its smallest part. The situation of this hole is shown in the engraving (fig. 1) by the tie of a ribbon that passes through it. The length of the hole is one and three-quarter inches, and it is cone-shaped from both sides.

This remarkable feature is almost without a parallel among meteorites. It reminds us of that great ring of meteoric iron,*

* See this Journal, II, vol. xiii, p. 289, and vol. xix, p. 161.

the "SIGNET" FROM ARIZONA, which weighs more than half a ton, the aperture being large enough for a man to crawl through. The presence of holes in masses of meteoric iron is difficult to explain. They may be caused by internal explosions, which, rending the sides asunder, leave, sometimes a bridge, or else a ring of metal, the explosions, resulting from the heat suddenly generated by the friction of the mass, in contact with the earth's atmosphere while the mass is moving at planetary speed.

An analysis, by Mr. James B. Mackintosh, of a piece cut from the edge, gave the following results:

Iron	91·22
Phosphorus	0·16
Nickel and cobalt	8·62 by difference.
	100·00

(Other elements not looked for.)

2.

Widmanstätten lines (natural size) on the Independence County, Arkansas, Meteoric Iron.

It belongs to the class "Holosiderite" of Brezina—being free of stony matter, and closely resembles the irons of Chulafinnee,* Alabama, and Whitfield County,† Georgia, previously described by the writer.

* This Journal, III, vol. xix, p. 370. † Ibid, vol. xxi, p. 286.

The small surface which in fig. 1 shows faintly and in reduced size the internal crystalline structure, is better shown in fig. 2; which is a reproduction of exact natural size, by the Ives process of photo-engraving.

The Widmanstätten lines in this iron are remarkably perfect, unusually so for so large a mass.

Troilite (FeS), having a bronze color and luster occurs as thin seams and veins on the polished face and extends far into the mass. Schreibersite, as rather large bright points, was also identified.

This is the second meteoric mass found in Arkansas, up to this date; the other being from Newton County,* where it was found in 1860. The latter differs from the Independence County mass in consisting of much olivine, bronzite and other stony matter.

2. The cuboidal mass of Meteoric Iron, from Laurens County, South Carolina.

This undescribed mass of meteoric iron was found in 1857 in the northwestern corner of Laurens County, South Carolina,

3.

Meteoric Iron (cuboidal), from Laurens Co., S. C. (natural size.)

and was deposited, soon after its discovery, in the cabinet of the Laurensville Female College, at Laurens Court House, S. C.

* This Journal, II, vol. xl, p. 213.

It remained there until it was sent to the Exposition at New Orleans in 1884 as a part of the South Carolina exhibit. The writer is indebted to R. W. Milner, President of the Laurensville Female College, for the above information, and also for the possession of the meteorite.

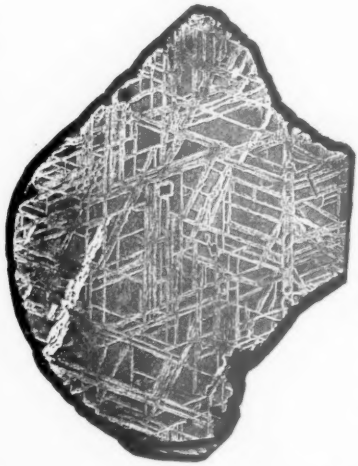
Its weight is four pounds and eleven ounces. Its shape is shown in fig. 3 which is of natural size.

The perfection of the Widmannstätten lines, as shown in the smoothed surface* of fig. 3, is unusual. Their fineness marks the mass as belonging to a class of rare meteorites.

The writer's attention was directed, at first, to the apparent *cuboidal* aspect of this mass, and with that idea, he had the panel smoothed out, as in fig. 3, merely to prove by the internal structure, whether or not this shape was accidental.

The relation of the etched lines to the profile gives evidence that in part, at least, the outward shape is due to a uniform crystallization of the mass. The perpendicular lines are nearly parallel to the two sides (this is better proved while examining the mass, in hand), and agree fairly enough with the top and bottom sides to be consistent with a cube. The back of the mass is bluntly pointed (cone shape) toward the left upper side and covered with large depressions.

4.



Wishing to further test the homogeneity of the mass, it was cut through at the base of the cone-shaped projection on the back and the surface shown in fig. 4 developed. Here the internal structure is exhibited even more beautifully than in fig. 3, and the angles are those which octahedral crystallization would present on a cubic face.

All over the mass a thin formation of limonite was observed, this coating being much thicker over the cuboidal faces than on the rough surfaces at the back. The thickness of this crust is well shown by fig. 4.

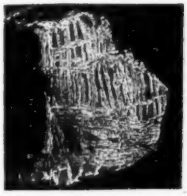
The dark rhomboidal spot near the middle of fig. 4 was found to consist of solid ferrous-chloride (Lawrencite). Several

* This surface was drilled out with a lathe, then smoothed, polished and etched with diluted nitric acid.

similar spots of this same rare species were noticed on the face shown in fig. 4. Their deliquescence first attracted attention to them. The presence of hydrogen (occluded) was proved by simply rubbing the smoothed surfaces with powdered sulphur, when instantly, the disagreeable odor of hydrogen sulphide was made noticeable. In the action of nitric acid on the smoothed surfaces the presence of carbon was also proved conclusively.

A few words as to what seems to be the point of impact when this mass fell. By referring back to fig. 3 and noticing the lower right hand edge a nearly straight surface of two centimeters length is seen, and as this was a natural flat surface I smoothed and etched it, with the result as shown in fig. 5. A set of lines, of structure at about 90° angle, is at once noticeable, as well as an increased fineness of detail as compared to the other figures. That this face is the place of impact the writer has no doubt after comparing its surface with the other figures.

5.



Laurens Co. iron.

A careful analysis by Mr. James B. Mackintosh yielded:

Iron	85·33
Nickel	13·34
Cobalt	0·87
Phosphorus	0·16
	99·70

Sulphur, trace. Carbon, undetermined.

These results place this mass among the few that are exceedingly rich in nickel and cobalt. It approaches in this regard the meteorites of Babb's Mill* (Green Co., Tennessee), Ni 14·73 per cent [mean of three analyses], and that of Kokomo† (Howard Co., Indiana), Ni 12·29 per cent. Its cobalt percentage is probably above that of any other on record, being nearly 1 per cent.

The Widmannstätten figures resemble in their perfection and abundance, those shown on the Smith Mountain‡ (Rockingham Co., N. C.) iron described by Smith. This is the fourth meteoric mass found in South Carolina; the others being known under the names of the Bishopville§ (stone); Chesterville;‖ and Lexington County ¶ (Ruff's Mt.) meteorites.

I take pleasure in here expressing my thanks to Mr. Mackintosh for his kindness in furnishing the above analyses.

Newark, N. J., Dec. 21st, 1885.

* This Journal, I, vol. xlix, p. 342.
† Ibid, III, vol. v, p. 155; and vol. vii, p. 391. ‡ Ibid, III, vol. xiii, p. 213.
§ Fell March 25, 1843. ‖ This Journal, II, vol. vii, p. 449.
¶ Ibid, II, vol. x, p. 128.

ART. XLV.—*Notice of a new Genus of Lower Silurian Brachiopoda;* by S. W. FORD.

SEVERAL months since Mr. Walter R. Billings, of Ottawa, Canada, sent me a number of wax impressions of the interior of a nearly perfect specimen of the ventral valve of the species described by the late Mr. E. Billings, in 1862, under the name of *Obolella desiderata* (Palæozoic Fossils, vol. i, p. 69). These impressions interested me very much, affording, as they did, more perfect knowledge of the internal structure of this species than had previously been obtained; and I subsequently received from Mr. Billings for study, the specimen itself, which belongs to his private collection, accompanied by the statement that, in case I might so desire, I was at liberty to publish a notice of it. This I some time since resolved to do; but various obstacles have prevented, until now, the fulfillment of my intention.

A careful study of Mr. Billings's specimen, and an examination of the original material used by the late Mr. E. Billings in his description of the species, kindly granted me by Mr. J. F. Whiteaves, have convinced me that *O. desiderata* may be taken as the type of a new genus, which will probably include several described Lower Silurian species. It differs from *Obolella* in

Genus BILLINGSIA, n. g.

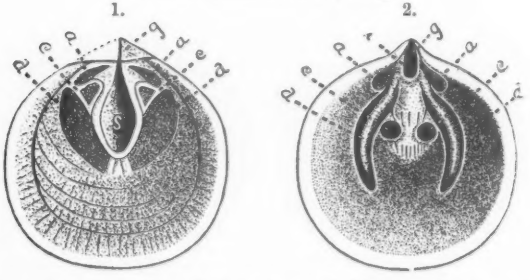


Fig. 1.—Interior of a nearly perfect specimen of the ventral valve of *Billingsia desiderata*, enlarged four diameters. *aa*, cardinal, *cc*, central and *dd* lateral muscular scars; *g*, the groove in the area; *s*, the spoon-shaped cavity beneath the beak or rostrum.

Fig. 2.—interior of the ventral valve of *Obolella crassa* Hall sp., enlarged about $2\frac{1}{2}$ diameters. *aa*, cardinal, *cc*, central and *dd* lateral muscular impressions; *g*, the groove in the area; *i*, pit into which the groove terminates.

the form and arrangement of its muscular impressions, in the possession of a thinner shell, and in other particulars. For this species I therefore propose a new generic name, BILLINGSIA, in honor of Mr. E. Billings, the late eminent Paleontologist of the Canadian Geological Survey.

Generic characters.—Shell thin, calcareous, inarticulate, longitudinally ovate or sub-circular, convex. Ventral valve with a solid beak and a minute area, which, in the typical species, is grooved for the passage of the pedicle as in *Obolella*. Muscular impressions in the ventral valve six, one pair situated close to the cardinal edge, one on either side of the median line; a second, smaller pair, placed directly below the former; and outside of the latter a third pair of large elongate or subreniform impressions, converging forward. Beneath the rostrum there is a prominent spoon-shaped pit or chamber separating the above mentioned impressions, with which the groove of the area is confluent. In the dorsal valve there are also three pairs of impressions disposed in nearly the same manner with those of the ventral valve. The dorsal valve is not known to possess an area. The surface is concentrically striated.

If we compare the interior of the ventral valve of *Billingsia desiderata* with that of *Obolella crassa* (see figs. 1 and 2) we shall find that they present several important differences. They coincide in this, that they each possess three pairs of muscular impressions; but the central pair in *B. desiderata* sustain a different relation to the cardinals than those of *O. crassa*, while the size, form and disposition of the laterals are plainly distinctive. Moreover, the large spoon-shaped cavity beneath the rostrum has not, so far as I am aware, any exact homologue in any known species of *Obolella*. Its large size and forward extension forbid our interpreting it as the homologue of the pedicle pit of *Obolella*, although the pedicle very probably terminated in it.

Obolella? ambigua Walcott (Paleontology of the Eureka District, p. 67, pl. 1, figs. 2 *a*, *b*, *c*, 1884) has also a thin shell, with muscular impressions similar to those of *B. desiderata*, and will probably fall into the same genus. *Obolella pretiosa* Billings and *O. Ida* Billings (Palæozoic Foss., vol. i, pp. 68 and 71) are also thin-shelled species; and, when their internal structure shall have been determined, will very possibly prove to be generically identical with *B. desiderata*. All of these species occur low down in the Silurian rocks, and apparently at about the same geological horizon; *B. desiderata* and *O. Ida* having been described from the Lévis formation of the Canadian geologists, *O. pretiosa* from the Sillery, and *O.? ambigua* from the lower portion of the "Pogonip group" of Central Nevada.

It is possible that *Billingsia* should be regarded as only a sub-genus of *Obolella*. My present impression however, is, that it probably sustains about the same relation to that genus, that the genus *Olenellus* does to *Paradoxides*.

Schodack Landing, N. Y., March 2d, 1886.

SCIENTIFIC INTELLIGENCE.

I. Physics and Chemistry.

1. *On the Law of Gaseous Flow.*—Hirn has published an extended memoir on the law of flow of elastic fluids, in which he has given the results of experiments made to determine whether a gas under a constant pressure flows into a reservoir where the pressure, also constant, is less than its own, with a velocity indefinitely increasing as the pressure in the reservoir decreases; or whether there exists a limiting velocity which is attained when this second pressure is zero. Theoretically two kinds of equations have been employed to express the law of flow. In one of these, the work of expansion is neglected; in the other, more recent, it is included. Comparing together the volume-equations of the two kinds, it appears that they both give a maximum value for the volume of gas flowing under constant pressure into a reservoir where the counter-pressure is variable. As to the velocity-equations, the former indicates a continual increase in velocity from zero to infinity with decreasing pressures in the reservoir; while the latter, or Weisbach's equation, on the contrary, gives velocities converging toward an upper limit, attained when the gas passes into an absolute vacuum. Experiment then is to be invoked to decide, 1st, whether there is such a maximum value for the volume of gas thus flowing, and 2d, whether the velocity of the flow tends toward a limiting value as the counter-pressure diminishes. The apparatus consisted of a weighted gasometer of known capacity, which forced air through a suitable orifice into a reservoir kept exhausted by a water-pump. Five forms of orifice were employed, two of which were simply conical openings in a thin plate of brass 3^{mm} thick, and the others conical ajutages, whose side formed angles of 13° and 9° respectively with the axis, one of the two latter terminating in a cylindrical glass tube. The pressure in the gasometer was maintained constant by the weights upon it, and the flow was measured by noting electrically its rate of fall. The varying pressure in the reservoir was also recorded electrically. Representing graphically the results of the experiments, it appears that the maximum value to which the volume-equations point has no existence; and that with regard to the velocity of flow, the limiting value indicated by the equation of Weisbach, has equally no foundation in fact. Hence the author concludes that the true law of gaseous flow produced by difference of pressure, is still unknown; and concludes by calling attention to the discrepancy between these results and those predicted by the kinetic theory of gases. According to this theory, dry air under a constant pressure would flow into a perfect vacuum with a velocity which cannot exceed that of the gaseous molecules themselves at that temperature, which is about 485 meters per second. But in the experiments above mentioned, even under a notable

counter-pressure, velocities of 6000 meters per second were observed; necessitating it would seem, a revision of the theory. —*Ann. Chim. Phys.*, VI, vii, 289–349, March, 1886. G. F. B.

2. *On the Existence of Nitryl Chloride.*—WILLIAMS has examined experimentally the common statement of the text-books that nitryl chloride not only exists but is readily prepared; making use of such reactions as seemed likely to afford this compound. In the first, phosphorus oxychloride was allowed to drop from a tap funnel upon pure dry lead nitrate contained in a flask connected with a condenser. But only a few drops of a yellowish red liquid were obtained; the gas which escaped continually, having the properties of chlorine, while reddish vapors appeared in the flask. Then in the same apparatus, pure nitric acid was allowed to drop on the phosphorus oxychloride contained in the flask. More distillate was now obtained but the oxychloride was also always present. On treating nitric acid and phosphorus oxychloride in equivalent proportions in sealed tubes for two hours at 100°, two layers appeared, the upper deep red and mobile, the lower yellow and viscid, most probably phosphoric acid. On opening the tubes, chlorine and hydrochloric acid gases escaped. Dry fused potassium nitrate was then placed in a test tube and sulphuric chlorhydrin was poured upon it. Heat was evolved and chlorine and nitrogen tetroxide were given off in large quantity. On passing the vapors through a condenser cooled to —18°, a small quantity of a deep red liquid was obtained which proved to be a solution of chlorine in nitrogen tetroxide. Sulphuryl dichloride was then sealed up with an equivalent quantity of potassium nitrate and heated to 100° for several hours. A certain amount of red gas was formed and on opening the tube chlorine was collected over hot water. Hence the author infers that in general whenever a nitrate is acted upon by an acid chloride, nitryl chloride is not obtained as such but only its constituents, nitrogen tetroxide and chlorine. Three series of experiments were made to form nitryl chloride by direct synthesis. In the first, the chlorine and nitrogen peroxide were passed through a red hot tube, as Hasenbach suggested. But since the tetroxide decomposes at a red heat into the dioxide and oxygen, it was probable that the product would be nitrosyl chloride; and this was found to be the fact, as was proved by analysis. In the second and third the mixture was passed through a large U tube, filled with broken glass and heated to 130°–150°. The product was a red volatile liquid, whose observed vapor density agreed best with that calculated on the hypothesis that all the chlorine was free. In the third series, however, the distillation was continued for a short time only and the accordance was closer. The author concludes therefore, that nitryl chloride cannot be formed by direct synthesis; the product, like that obtained by the other methods, being merely a solution of chlorine in nitrogen peroxide.—*J. Chem. Soc.*, xlix, 222–233, April, 1886. G. F. B.

3. *On a new Oxide of Zirconium, and on its use in the Determination of this element.*—While making an analysis of the mineral koppite, BAILEY found that a precipitate containing ferric oxide yielded a notable quantity of zirconia on treatment with tartaric acid and ammonium sulphide. On redissolving it and adding hydrogen peroxide to the solution, a white bulky precipitate was obtained which after washing, gave with hydrochloric acid and potassium iodide, on heating, free iodine; proving the presence of a peroxide. This reaction, Clève had observed about the same time, and had assigned to the new oxide the formula ZrO_3. To investigate this substance, Bailey prepared zirconium-potassium fluoride by Wöhler's method, converting this salt into the sulphate, and precipitated the solution directly with hydrogen peroxide. A portion of the moist peroxide was distilled with hydrochloric acid in a small flask, the distillate being passed into a solution of potassium iodide, and the iodine set free being determined by Bunsen's method. In the residue in the flask the zirconia was determined directly. The result gave Zr 69·564, O 30·436. Since the moist precipitate after standing three months gave Zr 69·284, O 30·716, the author infers that the new oxide is perfectly definite and stable. From these figures, the formula of the new oxide is Zr_2O_5. Freshly precipitated it is less readily soluble in dilute sulphuric acid than zirconia and hence the two may thus be separated in the cold. The author calls attention to this reaction as a convenient means of separating zirconium from the elements likely to be associated with it. Iron and alumina, as Clève has shown, are not precipitated by hydrogen peroxide, nor is titanium, niobium, tantalum, tin, or silicon. A very dilute solution does not effect the precipitation but with a moderately concentrated one the precipitation is complete. When of such a strength as to yield 120 vols. of oxygen on heating, hydrogen peroxide precipitates Zr_2O_5 at once and completely from its solution in sulphuric acid. Even if it yields only 20 vols. of oxygen, the solution effects a complete precipitation on standing for a short time.—*J. Chem. Soc.*, xlix, 149–152, March, 1886. G. F. B.

4. *On the determination of Vanadium by means of Oxycellulose.*—In studying the properties of oxycellulose, produced from cellulose by oxidation, WITZ observed, some time ago, the decided property which it possessed of fixing basic coloring matters, especially metallic oxides. In connection with OSMOND, he now suggests the use of this property in chemical analysis, since, other things being equal, the proportion of a base fixed on a given weight of oxycellulose is a function of the quantity contained in the bath. So that if the base is itself colored, or if it may produce color by the action of a convenient reagent, a very delicate reaction may thus be developed. In the present paper he considers its application to vanadium salts, using for this purpose the well known reaction with potassium chlorate for the preparation of aniline black. The method requires five operations: (1) preparation of the strips of calico partially

transformed into oxycellulose, by paste printing, (2) immersion in the vanadium bath for a definite time, rinsing and drying at 40°, (3) printing the strips sewed end to end, with bands of the usual mixture of aniline black less the vanadium, (4) developing the black in the oxidation chamber, and (5) classification. In testing the process, hypovanadic chloride was prepared from the metavanadate of ammonium by the action of hydrochloric acid, the reduction being effected by means of glycerin, the excess of acid being removed by evaporation, and the solution diluted. Six baths were thus prepared, containing progressively decreasing quantities of vanadium from one tenth to one millionth of a milligram per liter. The duration of the immersion was 8 hours at 15°. The specimens were prepared by Osmond at Creusot and classified by Witz at Rouen. The order of classification was exactly that of the dilution, the strip treated in the sixth bath which contained only one millionth of a milligram of vanadium per liter being sharply distinguishable from that treated with pure water. The authors give the effects produced by the presence of foreign salts upon the result, and say that by this test they have been able to detect the presence of vanadium in the water supplied to Creusot and in the mineral water of Saint Honoré-les-Bains; but not in the body of a sheep of the region.—*Bull. Soc. Chim.*, II, xliv, 309–315, March, 1886. G. F. B.

5. *On the Physical Properties of the C_nH_{2n+2} series of Hydrocarbons from American Petroleum.*—Bartoli and Stracciati have examined the physical properties of twelve hydrocarbons of the marsh gas series prepared by careful fractioning, from Pennsylvania petroleum. They find that as the molecular weight increases, (1) the expansion-coefficients, both between 0° and 30° and between 0° and the temperature of ebullition, decrease regularly; (2) the molecular volumes at the boiling point are not the same as those which are calculated by Kopp's formula; an increase of CH_2 not always corresponding to the same increase of molecular volume, the differences being superior to errors of observation; (3) the capillary constants a^2 and α, measured at the ordinary temperature, increase continuously, thus disagreeing with Wilhelmy's result; (4) the coefficients of friction at the temperature of 22° to 23° increase rapidly and with regularity; (5) the index of refraction measured for the line D, increases regularly; (6) these hydrocarbons have nearly the same specific heat; (7) they do not conduct the electric current; and (8) they have specific inductive capacities which follow Maxwell's law. The precise values are given in a table.—*Ann. Chim. Phys.*, VI, vii, 375–383, March, 1886. G. F. B.

6. *On the Synthesis of Conine.*—Ladenburg has studied the reaction of paraldehyde upon α-picoline, with a view to the synthesis of conine. The reaction requires a high temperature, the yield even at 250° being small. The product was an oily liquid difficultly soluble in water, having a boiling point at 190°–195° and having an odor like conyrine. Analysis gave numbers

near those of an allylpiperidine. This oil readily underwent reduction and gave almost the theoretical quantity of a base the hydrochlorate of which was a white crystalline permanent salt. The cadmium-double iodide was prepared, and like that of conine, was an oily liquid solidifying on contact with a crystal-fragment. On re-crystallization it gave well formed crystals exactly resembling the conine salt, fusing at 117°–118°, and affording coincident numbers on analysis. From the mother liquors a base was obtained which had the odor and solubility of conine, and which boiled at 166°–170°. The hydrochlorate made from this formed brilliant needles fusing at 203°. The author believes therefore that the new base is probably identical with conine.—*Ber. Berl. Chem. Ges.*, xix, 439–441, March, 1886. G. F. B.

7. *On the Chemical Action of Bacterium aceti.*—Brown has studied the chemical action of pure cultivations of *Bacterium aceti* upon various organic substances. The ferment used was originally taken from the surface of a beer which had been exposed to the air in a warm place till acetic fermentation had set in. It was inoculated into the first of a series of 10 test tubes, containing a sterilized solution of 2 per cent ethyl alcohol in yeast water; an inoculation being made to the next tube as soon as a visible growth was observed. Ethyl and propyl alcohols were readily converted into acetic and propionic acids respectively. Dextrose in a 2 per cent solution, yielded gluconic acid. Sucrose in a 4 per cent solution, underwent no change. Mannitol was completely oxidized by *B. aceti* and yielded mainly levulose. By sodium amalgam, this levulose as well as that from inulin and invert sugar may be re-converted into mannitol.—*J. Chem. Soc.*, xlix, 172–187, March, 1886. G. F. B.

II. Geology and Mineralogy.

1. *Note on the occurrence of* Olenellus (?) Kjerulfi *in America*; by F. G. Matthew.—A good deal of interest attaches to the occurrence of this species in America, as its position in Europe is beneath that of the beds carrying Paradoxides, while in America the genus Olenellus is supposed to belong to the Middle Cambrian—the horizon corresponding to the Olenus-bearing measures of Europe.

In New Brunswick this species has not been found in the St. John Basin of Cambrian rocks, but it occurs in that of the Kennebecasis river, where it is associated with a number of species found in the St. John Basin in the bands *c* and *d* of Division I. The species are similar and in some cases identical with those of the Menevian Groups of Wales. The band *c* of the Saint John Basin which corresponds more nearly to the Solva group in its fauna than to the Menevian, has been well explored, and if *O.* (?) *Kjerulfi* were common in it, it would probably have been found ere now; but it has not been met with. If this species were

present in America at a horizon corresponding to that at which it occurs in Europe it should show itself in band *b* of Division I, but so far it has not been recovered from this horizon; on the contrary the species found to be associated with it in the Kennebecasis Basin are mostly those that belong to band *d* or higher measures.

In Newfoundland *O.* (*?*) *Kjerulfi* occurs in association with *Agraulos strenuus*, *Hyolithes Micmae*, etc. The two species named occur in Division I, band *c* in the St. John Basin, and the second occurs also in *d*.

Olenellus (*?*) *Kjerulfi*, was originally described as a Paradoxides by Linnarsson, but Prof. W. C. Brögger referred it subsequently to Olenellus. It is perhaps doubtful if the species belongs there: the peculiar pygidium of Olenellus has not been recorded in connection with it, and the eyelobe is that of Paradoxides. But on the other hand the glabella is not enlarged in front as in the true Paradoxides, and all the furrows turn backward as in Olenus and other genera of the Middle Cambrian. Among true Paradoxides, *P. Acadicus* in its straight-sided glabella, its moderately arched and uniformly narrow eyelobes, and its granulated test, appears to be more closely allied to this species than any other.

St. John, N. B., April, 1886.

2. *Geological formations underlying Washington and vicinity. Report of the Health Officer of the District of Columbia, for the year ending June* 30, 1885. [By SMITH TOWNSEND, M.D., Health Officer.] Washington, 1886. (8vo, pp. 1–160, folding plates 1–16+3.)—In addition to the customary sanitary, hygienic, statistical and administrative matter, this report contains the substance of a communication from the office of the U. S. Geological Survey, embodying some preliminary results of an elaborate survey of the District of Columbia, in which the formations underlying Washington and its environs are for the first time clearly discriminated and named.

It appears that Washington is located in a triangular depression or amphitheatre, rising 20 to 80 feet above tide, bounded on the east, north, and southwest by bluffs rapidly ascending by successive terraces to altitudes of 150 to 300 feet, and traversed by the Potomac river, the Eastern Branch, and some minor streams. Within this amphitheatre and rising about its periphery (except on the east) to an altitude of about one hundred feet is a well defined Quaternary deposit to which the name *Columbia formation* is applied. Its upper portion consists of loam or brick-clay, and its lower of sand, gravel, bowlders (up to four or five feet in diameter), or all combined. Its thickness is variable, the upper member ranging from almost nothing to perhaps 20 or 30 feet, and the lower from perhaps 1 to 20 feet. The deposit is more or less distinctly stratified throughout, particularly in its lower division; and at the base it frequently becomes a simple bed of bowlders and gravel, without considerable admixture of finely comminuted materials. The entire formation appears to

represent a subaqueous delta of the Potomac river, formed when the sea rose far above its present level and fashioned the marine terraces exhibited in the bluffs. Its absence above sea level east of the Eastern Branch may be attributed to a dislocation (of which there is other evidence) trending parallel with the Appalachians and the Atlantic coast. The most extensive formation in the District is that hitherto known as "Newer Mesozoic" in Virginia, and "Iron Ore Clays" in Maryland. It is denominated the *Potomac formation.* In structure and composition it is bipartite, the upper portion consisting of highly colored banded and mottled clays, with intercalations of sand and quartzose gravel, and the lower of sand and gravel with intercalations of clay. In both divisions stratification is inconstant and often absent, and the materials are sometimes indiscriminately intermingled. The formation is practically destitute of fossils in the District, but yields abundant plant-remains in Maryland and Virginia. It appears to consist of inosculating deltas of the Potomac and other Atlantic coast rivers and the littoral deposits into which they merge, laid down along a bay-indented coast upon a highly inclined and irregular sea-bottom produced by combined depression and sea-ward tilting of a deeply corroded land surface in late Jurassic or early Cretaceous time. The Potomac formation rests everywhere on the eroded edges of highly inclined gneiss which has not yet been thoroughly studied, but which is probably an extension of that of New York and Philadelphia.

W. J. McG.

3. *Theories of Ore-deposits;* by M. E. WADSWORTH. (Proc. Boston Soc. N. Hist., xxiii, 197.)—Professor Wadsworth, after referring to a tendency to change in the minerals of igneous and metamorphic rocks, and speaking of the unstable condition as a consequence of origination at high temperatures, explains the changes by appealing to "percolating waters" and "external agencies," and refers to the same causes the "segregation or localization of ores" into veins, where such veins are not directly of igneous origin. His closing paragraph (p. 203) is as follows: "The general alteration manifests itself in a universal chemical or molecular transference—a transference of material, leading to the segregation or localization of the ores in the places in which they are now found; it manifests itself in the deposition of mineral matter in the veins and cavities of the rocks themselves, in deposits from springs in bogs, lakes, etc. From this it would follow that all ore-deposits not eruptive are superficial phenomena as regards the earth and dependent on its external agencies, although they may be deep enough so far as man is concerned. Again, few of these ore-deposits would be expected except in regions in which percolating waters and their resulting metamorphism have been efficient agents; while the various forms of ore-deposits would be expected to be associated with and grade into one another."

The method urged appears to exclude any aid in the making of veins from vapors of water or other material ascending from the

depths of fusion along with the igneous rock, and also, the agency of any vaporized materials derived from the walls of the fissures through the heat, any part of which walls may, as far as is known, yield ores, and the last few miles of which may intersect rocks containing a per cent or so of moisture (0·6 per cent would be a pint to the cubic foot of rock), or holding bodies of fresh or salt water between the beds. Subterranean waters have come from above and may be included among "external agencies;" and if so, the theory is wide enough to cover a large part of vein-making, and so far falls in with views that have been advocated by others.

4. *On Slaty Cleavage and allied rock structures with special reference to the mechanical theories of their origin;* by ALFRED HARKER, M.A., F.G.S. Brit. Assoc. Rep. for 1885.—This is a thorough, partly mathematical, and judicious discussion of the subject of slaty cleavage. The general conclusion is expressed in the following statement from page 38: "The theories discussed in the foregoing pages make the cleavage of rocks a result of lateral thrust operating throughout larger or smaller tracts of country; and the extreme stages of the structure, which involve mineralogical as well as lithological changes, a consequence of the intense stresses in the earth's crust to which mountain-systems owe their structure." While admitting that the impression of the cleavage structure is of later date, in the main, than the tilting and flexures observable in them, he still regards the cleavage and folding as concomitant though not simultaneous effects of the same lateral pressure.

5. *Index der Krystallformen der Mineralien* von Dr. VICTOR GOLDSCHMIDT. Vol. I, part 1. 280 pp., large 8vo. Berlin, 1886 (Julius Springer).—The task which the author has undertaken is one of very great magnitude, namely, the presentation of a complete catalogue of the forms observed on the crystals of each mineral species, with the names of the observers, the letters employed by different authors, the literature, and so on. The part now issued, of 288 pages, is only half of the first volume, and the whole work is to consist of six such parts in three volumes. The Introduction includes the development of the special symbols employed by the author, with the forms of calculation adapted to them, and also a very thorough explanation of the mutual relations of the different systems of notation for the planes of crystals from Haüy down. The author's general symbol (except in the hexagonal system) takes the form pq, which is equivalent to the hkl of Miller reduced to a form where the l is unity, that is, in general $pq = \frac{h}{l}\frac{k}{l}$. It is shown that this form brings out clearly the relations of the planes and lends itself easily to purposes of calculation. Those who have become familiar with the system to which the name of Miller is ordinarily attached will be slow to believe that any other system can be at once so clear and convenient, and will be likely to go further and question the desirability of introducing a new system at a time when so great a

degree of uniformity has been attained among the workers in all countries. The author, however, may fairly be regarded as having won for himself the right to have his methods carefully studied, and their claims fully considered, by the admirably thorough and complete way in which he has expounded the not often understood systems now gone out of use, especially those of Mohs and Hausmann. The same exhaustive methods have been devoted to the elaboration of the catalogues of planes, as the frequent lists of corrections that are given for the statements of earlier authors show, and to the complete tables for transforming the symbols from the form belonging to the position of one author to that of another. In this matter of the orientation of the crystals of each species, the author has shown himself more arbitrary than could have been desired. Simplicity of form of the symbols is in his view the one controlling condition, to which questions of isomorphous relations ("analogies") and all other points are to be subordinated. Thus he deviates from the accepted position for aragonite, although the reasons for its acceptance are so strong, and makes the prism a macrodome, and similarly in many other cases. The work, however, is one which no thorough mineralogist should be without, even if he is not inclined to follow it in all respects.

6. *Catalogue of Meteorites.*—A new catalogue of the large collection of meteorites in the British Museum has been recently issued by Mr. L. Fletcher. The catalogue is also a guide to that department of the Museum and contains an interesting "introduction to the study of meteorites." As is well known, the collection is one of the finest of the world both as regards numbers and the size of the specimens represented; 360 distinct falls are included in the catalogue.

7. *Brief notices of some recently described minerals.*—Emmonsite is a ferric tellurite from the neighborhood of Tombstone, Arizona, exact locality unknown. It occurs in translucent crystalline scales of a yellowish green color, imbedded in a hard brownish gangue consisting of lead carbonate, quartz and a brown substance containing the hydrated oxides of iron and tellurium. The crystallization is probably monoclinic, the specific gravity about 5. The material was scanty and not entirely pure, so that the results of the chemical analyses were somewhat doubtful. The mean percentages accepted, after deducting impurities, are: Te 58·75, Se 0·53, Fe 14·29, H_2O present, but amount uncertain. It is concluded that the mineral is a ferric tellurite, but the formula is doubtful and further examination is needed to establish its true relations. Dr. Genth states that it is distinct from his *ferrotellurite*. Named after Mr. S. F. Emmons, of the U. S. Geol. Survey, by W. F. Hillebrand.—*Proc. Col. Sc. Soc.*, ii, part I, 1885.

Kainosite (from *καίνος*, unusual) is from Hitterö, Norway. The only specimen known is a fragment of a large six-sided prism (orthorhombic or monoclinic), showing two cleavages at an angle of nearly 90° with each other. It is translucent, of a yellow-

brown color and greasy luster. The hardness is 5·5 and the specific gravity is 3·413. The mean of two analyses of material dried at 100°, gave :

SiO_2	$Y_2O_3Er_2O_3$	Ce_2O_3	CaO	MgO	FeO	Na_2O	CO_2	H_2O
34·63	37·67	*tr.*	15·95	0·03	0·26	0·40	5·90	5·26=100·10

The composition of the mineral is so remarkable that it is to be hoped that more specimens for examination may be found. A. E. Nordenskiöld in *Geol. För. Förh., Stockholm*, viii, 143, 1886.

HYDROGIOBERTITE is a hydrous carbonate of magnesium occurring in spherical forms which are compact and of a light gray color. Imbedded in them are minute crystals of magnetite. The specific gravity is 2·149–2·174. An analysis yielded :

MgO	CO_2	H_2O
44·91	25·16	29·93 = 100

which corresponds closely with the formula $2MgO, CO_2, 3H_2O$. The mineral was found in an isolated mass of augite porphyry from the neighborhood of Pollena.—E. Scacchi in *Rend. R. Accad. Napoli*, December, 1885.

8. *The various forms in which gold occurs in nature.*—Professor W. P. BLAKE has contributed to the Report of the Director of the U. S. Mint for 1884 an article of twenty-five pages on the forms of native gold. He summarizes the observations of the various authors, giving a series of figures of the commonly occurring forms of crystals; to these he adds some original observations upon the peculiar distorted and cavernous crystals from California, which are fully illustrated. The remarks on the occurrence of gold in different localities, upon gold nuggets, and other points will also be read with interest.

III. BOTANY.

1. *Handbook of Plant Dissection;* by T. C. ARTHUR, M.Sc., CHARLES N. BARNES, M.A., and JOHN M. COULTER, Ph.D., editors of the Botanical Gazette. New York: Henry Holt & Co. 1886; pp. 256, 12mo.—These three active botanists and teachers, mostly Professors in Indiana colleges, where botany is much in advance, have conspired to furnish their students and all others who may be advantaged thereby with a succinct manual for laboratory use in elementary vegetable biology. Their work appears to be a very painstaking and faithful guide and helper to a kind of botanical work which is now popular, and for which great and various facilities—instrumental and other—have recently been supplied, by which such investigation is rendered practicable and profitable. So that now—thanks to the increase of good teachers, and of such helps as books of this sort—histology and organogeny are becoming a part even of elementary botanical education. The results are hopeful. For intending medical students, who cannot pursue botany far, and who early need this special

training, the biological laboratory offers the most needful training from the beginning. But it may be questioned whether, for common education, there is not a tendency to introduce histology too early into the course; also to treat it too technically and so to say Germanically. This tendency is most natural under the circumstances; but as our writers and teachers grow stronger in their grasp, they may be expected to discard a deal of superfluous terminology,—some wholly superfluous, more of it unnecessary for the occasion. Among these terms perhaps the most abhorrent are those (such as pollen-spores) which come from taking Cryptogamia as the norm, and imposing its terminology upon Phanerogamia. Nomenclature is one thing: homology is another. We do not usually say "stamen-leaves" and the like. The Germans of our day excel in investigation and supply excellent material. But they seem to lack the gift of exposition and the sense of proportion; and so, for educational purposes, their writings need something more than translation.

The remarks we have been led into are not specially *apropos* to the present little book, which is a really commendable one for its purpose. A. G.

2. *Japanese Botany.*—The sixth fascicle of *Diagnosis Plantarum Novarum Asiaticarum*, by Dr. Maximowicz, of St. Petersburgh, issued in February, 1886, contains several Japanese plants, communicated with drawings, and named by *Itô Tokutaro*. Among them is "Podophyllum Japonicum, *Ito*," of which, as we understand, Maximowicz has seen a drawing only of the flowering plant, and analytical figures. It differs from other species of the genus in having ternate leaves, is 6-petalous and 6-androus; and, as the dehiscence of the anthers is not made out, the genus is quite uncertain. There is also another species from Japan, so very like our own *P. peltatum* that Maximowicz so names it, with a mark of doubt, because it has only six stamens. Formerly only our single American species was known; now we have indications of four or five East Asian and Himalayan species. Other notable plants described in this paper are such as a new *Microrhamnus* from Japan and China; and *Platypholis*, a genus from Bonin Islands near to *Conopholis*. In a review of the genus *Gleditschia*, Dr. Maximowicz shows that two Chinese species go far to invalidate *Gymnocladus*, a genus which we had supposed was most distinct. A. G.

3. *American Desmidieæ.—Bidragtill Amerikas Desmidie-flora*, of G. LAGERHEIM, is the title of a well-elaborated paper, separately issued from the Proceedings of the Royal Academy of Science of Stockholm, xlii, No. 7, published at the close of the last year. A good share of the specimens here studied and systematically enumerated are said to have been derived from the bladders of *Utricularieæ* preserved in herbaria, notably those of the Stockholm Museum and at Upsala. The author's method of preparation is detailed in the Bot. Centralblatt, xviii, No. 19, 1884. His principal habitats are Cuba, Georgia, and Tewksbury,

Mass.; the former derived from the late Charles Wright's collections, the latter from those of our old friend the late B. D. Greene, who largely collected aquatic plants in Tewksbury swamp, while the collector in Georgia seems to be unknown. A double plate contains figures of thirty species. Sixteen species are new or newly named and characterized. A. G.

4. *Notarisia.* Edited by Drs. G. B. DE TONI and DAVID LEVI. Venice, 1886.—Following the custom of mycologists in naming their journals in honor of leading mycologists, two young Venetian phycologists have started a journal to be devoted to the interests of phycology and have named it after the distinguished Italian cryptogamist, the late Professor G. de Notaris. The journal is to be issued quarterly, and the first two numbers, which have already appeared, give evidence that it will be of great service to students of Algæ. There is a summary of species of marine and fresh-water Algæ recently described, together with a review of recent papers on Algæ. The reviews and summaries are very convenient, as they present in a compact form the results of papers scattered through a large number of journals. The descriptions of species are in Latin, but it is to be regretted that the reviews are in Italian, a language which comparatively few botanists can read with accuracy. As all educated Italians can read and write French with ease, it would probably not be difficult for the editors to substitute French for Italian in their journal, a change which would be welcomed by all foreign subscribers, on whom Notarisia must depend largely for support. The journal also has some original articles of value by Lagerheim, who writes in French, and Borzi, while the editors contribute a scheme of the genera of *Florideæ* adapted to Ardissone's Phycologia. The articles are illustrated by several lithographic plates. W. G. F.

5. *Phycologia Mediterranea.* By Professor F. ARDISSONE. Varese, 1883.—Professor Ardissone, the Director of the Botanic Garden of Milan and President of the Societa Crittogamologica Italiana, published in 1883 the first volume of his Phycologia Mediterranea in the Memoirs of this Society; but it is not until recently that copies have been received in this country. It includes the *Florideæ* and *Dictyotaceæ*, and forms a large, well-printed volume of over 500 pages. The algæ of the Mediterranean have been studied by botanists of reputation for many years, but there has not hitherto appeared any work treating of them collectively. The first part of the Phycologia is all that the reputation of the author as the leading phycologist of Italy would lead one to expect. The synonymy is full, the descriptions clear and never diffuse, and the notes on distribution and microscopic structure show a wide reading and large study. It is to be hoped that Professor Ardissone will soon be able to issue a second volume including the remaining orders and thus supply the great want of a complete treatise on the marine flora of the northern coast of the Mediterranean. W. G. F.

IV. Astronomy.

1. *Traité de la détermination des orbites des comètes et des planètes, par* Chevalier d'Oppolzer; édition française par Ernest Pasquier. Vol. i. Paris: Gauthier-Villars. 1886. Large 8vo, pp. 491 and ccix.—The great work of d'Oppolzer is too well known to astronomers to need comment, being decidedly the most complete and satisfactory work on orbits in existence. This translation by the Louvain professor (published at his own charges) makes the work easily accessible to those to whom the French language is more familiar than the German. It is made from the second edition of the first volume of the original. The translator had the advice and assistance of the author. He has taken care to have the work, but more especially the tables, accurately printed. There have been changes both in the text and in the tables, but in the main the volume is a reproduction of the original.

This first volume is complete in itself, but it is certainly to be hoped that Professor Pasquier will be sufficiently encouraged to issue the second volume also. H. A. N.

2. *Publications of the Washburn Observatory of the University of Wisconsin.* Vol. iv, 8vo. Madison, 1886.—This volume contains several smaller articles, but the greater part of it is occupied with observations of the 303 southern fundamental stars for the zones of the *Astronomische Gesellschaft.* Of these in nearly every case six complete observations were obtained. The later observations, to complete the scheme, were made by Mr. Updegraff and Miss Lamb after Mr. Holden's appointment as President of the University of California, and are given in an appendix. H. A. N.

V. Miscellaneous Scientific Intelligence.

1. *Elisha Mitchell Scientific Society* (Raleigh, N. C.) *for the year* 1884–1885. 100 pp. 8vo.—This report opens with a sketch of the botanical work of Dr. M. A. Curtis (an obituary notice of whom, by Dr. Gray, was published in III, vol. v, 1873, of this Journal), and also a brief notice of Prof. Kerr. Among the notes in the following pages, which are mainly chemical and meteorogical, there are papers by Prof. Kerr on the distribution and character of the Eocene deposits in eastern North Carolina, and on the geology of the region about Tampa, Florida. On pp. 39, 40, Prof. F. P. Venable gives the results of analyses of the leaves of the Yopon or Ilex Cassine of North Carolina—the tree that afforded, by a steeping of the leaves, the famous "Black Drink" of the Southern Indians, which they used for medicinal (drastic) purposes. The dried leaves, collected in winter, were found to afford caffeine, 0·32 per cent. In an analysis made of leaves collected in May and dried, 0·27 per cent of caffeine was obtained, of tannin 7·39, nitrogen (on combustion) 0·73, ash 5·75; and the

ash contained in 100 parts P_2O_5 3·34, SO_3 2·50, SiO_2 1·32, Cl 0·66, Fe_2O_3 0·26, MnO_2 1·73, MgO 16·59, CaO 10·99, K_2O 27·02, Na_2O 0·47. The Maté or Brazilian Holly (Ilex Paraguayensis), according to Peckolt, affords from its dried leaves 0·639 per cent of caffeine; but the ash contained affords (as analyzed by Arate) only 2·98 of K_2O, with Na_2O 7·28, P_2O_5 5·54, SiO_2 44·75, Cl 0·71, SO_3 0·92, Fe_2O_3 3·41, MnO_2 2·50, MgO 11·39, CaO 12·34.

2. *Report on the work of the International Geological Congress.*—Dr. Frazer states to the Editor of this Journal that in his report, noticed on page 403, there are two typographical errors: on page 41, 16th line, Bergakademic should be Bergakademie; and page 44, 2d line, J^2 should be J ?.

3. *National Academy of Sciences.*—The following are the titles of the papers entered to be read before the Academy at the session of April, 1886, at Washington:

H. A. Newton: The Comet of Biela.

H. A. Rowland: On the absolute and relative wave lengths of the lines of the Solar Spectrum.

Ira Remsen: Influence of Magnetism on Chemical Action.

Wolcott Gibbs: Platinous compounds as additive molecules.

S. P. Langley: On the Invisible Spectra.

A. W. Wright: Crystallization of Platinum by means of the electric discharge in vacuo;—Effect of Magnetization on the Electrical resistance of metals.

A. M. Mayer: On the diathermancy of Ebonite and Obsidian, and on the production of Calorescence by means of Screens of Ebonite and Obsidian;—On the Coefficient of Expansion of Ebonite;—On the determination of the Cubical Expansion of a solid by a method which does not require calibration of vessels, weighings or linear measure;—On measures of absolute Radiation.

Ogden N. Rood: On color contrast.

R. E. Peary, U. S. N.: On a proposed Expedition into the interior of Greenland during the present summer with Disco as a base. (By invitation.)

Elias Loomis: Areas of High Barometric Pressure over Europe and Asia.

G. K. Gilbert: The Geologic Age of the Equus Fauna.

T. Sterry Hunt: The Cowles Electrial Furnace.

G. F. Becker: Cretaceous metamorphic rocks of California. (By invitation.)

Chas. D. Walcott: Classification of the Cambrian System of North America. (By invitation.)

E. D. Cope: On the Geology of the region near Zacualtipan, Hidalgo, Mexico;—On the Phylogeny of the Batrachia;—On the Phylogeny of the Placental Mammalia.

S. H. Scudder: The Cockroach in the past and in the present.

Theo. Gill: The ordinal and super-ordinal groups of Fishes.

W. K. Brooks: The Stomatopoda of the "Challenger" collection;—Budding in the Tunicata.

Edward S. Morse: On ancient and modern methods of arrow release.

Alexander Graham Bell: Upon the Deaf and Dumb of Martha's Vineyard (continuation of Research relating to the ancestry of the Deaf).

4. *The Library* of the late Professor Guyot is offered for sale by Mr. E. Sandoz, of Princeton, N. J. It is rich in works in the departments of General and Physical Geography, and in scientific publications of all kinds, including maps. The number of vols is about 4000, and of pamphlets and periodicals about 3000. The price per volume is $1.20, and for the pamphlets and periodicals 10 cents each.

5. *S. W. Ford's article*, p. 466, fig. 1 is enlarged 5 times, and fig. 2, nearly 3.

OBITUARY.

CHARLES UPHAM SHEPARD.—Professor Shepard died, after a short illness, on the first of May last, at Charleston, S. C., where for many years he had spent his winters. He was born in Little Compton, R. I., in the summer of 1804, and hence had nearly completed his eighty-second year. But until his last illness he was still young in his ardent devotion to his favorite science, his delight over the rare and beautiful among minerals, whether in his own cabinet or that of another, and his zeal for collecting and discovering new facts and new species; and not less young in his cheerful and kindly nature.

After graduating at Amherst College in 1824, he became a student of Professor Nuttall's at Cambridge in Botany and Mineralogy, and soon after engaged at Boston in instruction in these branches. At the same time he commenced his publications on mineral localities and their minerals, in this Journal.

In 1827, Mr. Shepard accepted the position of assistant to Professor Silliman in Chemistry, Mineralogy and Geology, which he retained, to the great satisfaction of the Professor, for four years. While thus engaged he also continued, during leisure weeks, his field and laboratory work in mineralogy. "A Mineralogical Journey in Northern New England," including a study of the remarkable localities of Acworth, N. H., and Paris, Me., and "The Mineralogy and Geology of Orange County, N. Y., and Sussex County, N. J.," illustrated by a detailed map of the various mineral localities, are the titles of two of the many papers published by him at that time; and they indicate his desire to give others a knowledge of localities, as well as to make known the results of his investigations.

In 1832, Professor Shepard published the first part of a "Treatise on Mineralogy," in which the system of the eminent Austrian mineralogist, Mohs, was adopted as to nomenclature and as to the natural history idea of mineral species. The second or descriptive part of the work, containing the descriptions of the species arranged in alphabetical order, appeared in 1835. This delay in its publication was partly owing to Professor Shepard's acceptance, from the general government, for the winter of 1832–33, of an appointment as an associate with Professor Silliman, for the investigation of the methods of sugar culture and manufacture in the Southern States, and to the preparation of his report on the subject, which was incorporated with that of Professor Silliman made in 1833 to the Secretary of the Treasury. In the same year, 1835, he joined Dr. Percival by appointment from the State legislature, in the Geological Survey of Connecticut; and two years later, in 1837, appeared his excellent report on the mineralogy and mineral products of the State.

His professorial work after 1832 was divided between New Haven, Conn., Amherst, Mass., and Charleston, S. C. To his duties at Yale under Professor Silliman were added those of Lecturer in Natural History, which position he held for fifteen years.

From 1845 to 1852, and from 1861 to 1877, he occupied the chair of Chemistry and Natural History in Amherst College. In 1854, he was called to the Professorship of Chemistry in the South Carolina Medical College at Charleston; he continued there until 1861, and again resumed the duties of the chair in 1865, after the civil war, resigning them finally in 1869, when his son, Charles U. Shepard, Jr., was appointed his successor.

These university engagements interrupted but little his mineralogical work. His first new species, microlite, was announced in this Journal in 1835, Warwickite in 1838, and Danburite in 1839. Other discoveries followed these, occasionally of new species, often of kinds not before identified on the continent.

Professor Shepard's private collection of minerals, under so great personal activity, became large and choice, surpassing all others on the continent. On retiring from his professorship at Amherst the whole was purchased by Amherst College. Unfortunately it passed from under his care to a building that was not fire-proof, and one night in 1880 it was nearly all destroyed. Professor Shepard did not cease collecting when he and his cabinet parted; but with his old zeal redoubled by the sight of empty shelves and drawers, he soon had again a large collection; and it continued to increase and to grow in interest with him to the close of his life.

Professor Shepard early commenced also the collection and study of meteorites, and through his life these shared with minerals in his affections and his labors. In 1829, nearly sixty years since, his first paper on the subject was published in this Journal; and others followed, until the number reached nearly forty, the series closing with one in the last volume (September, 1885). His collection grew, each paper being usually based on one or more acquisitions; and it was long the largest in the country. It became like the minerals, and with them, the property of Amherst College.

Dr. Shepard's zeal to the end knew no flagging, and he had the satisfaction of seeing great progress in his two departments, that of meteorites and that of minerals, through his labors. His knowledge of mineral species was unsurpassed in the land; and he was hence ready with quick judgments as to new and old; sometimes too quick—but in any case imparting progress to American Mineralogy.

Dr. Shepard was several times in Europe and had the personal acquaintance of many European mineralogists. He was a member of various American and Foreign societies; among them, the Imperial Society of Naturalists of St. Petersburg, and the Royal Society of Göttingen. He was a man of refinement and great courtesy, and was held in very high esteem in Charleston, S. C., as well as at his northern homes. His place of residence since leaving Amherst, and for much of his life before, was New Haven. He leaves two children, a son and a daughter.

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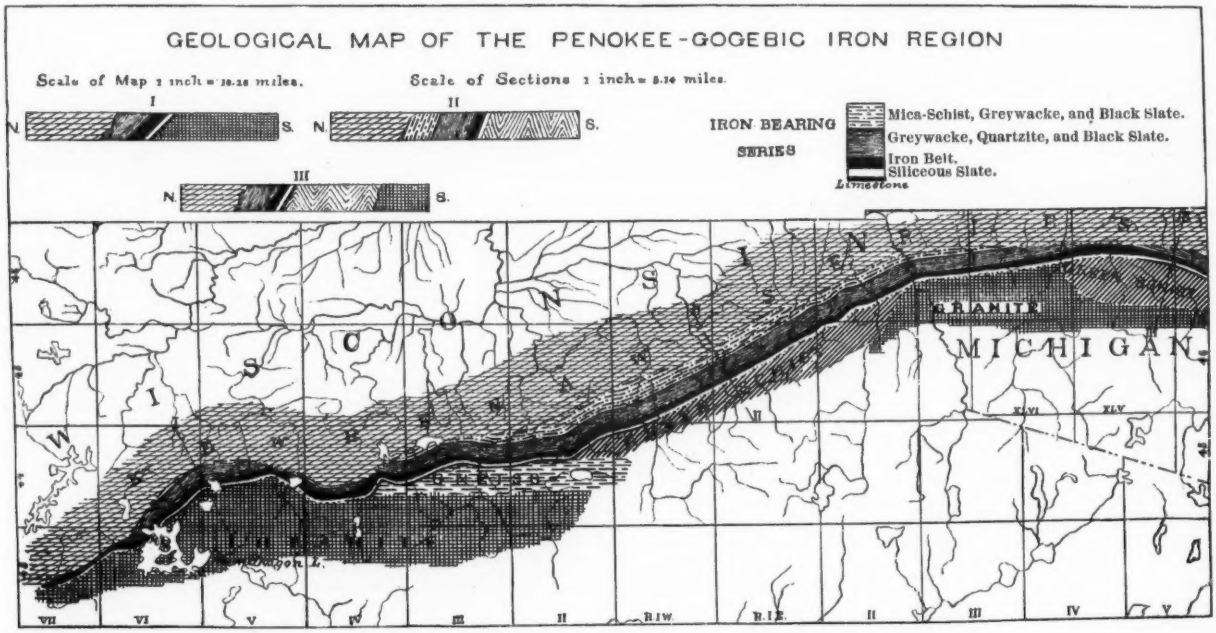
GEOLOGICAL MAP OF THE PENOKEE-GOGEBIC IRON REGION
Scale of Map 1 inch = 10.25 miles.
Scale of Sections 1 inch = 5.12 miles.
I
II
III
N.
S.
IRON BEARING SERIES
Mica-Schist, Greywacke, and Black Slate.
Greywacke, Quartzite, and Black Slate.
Iron Belt.
Siliceous Slate.
Limestone
WISCONSIN
MICHIGAN
GRANITE
Lake L.
VII
VI
V
IV
III
II
R.1W.
R.1E.
XLVI
XLV